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Factors Limiting the Western Range of *Arceuthobium Douglasii* in Oregon—a Hypothesis

Abstract

Relatively recently a number of stands of Douglas-fir, which are infected with *Arceuthobium douglasii,* have been found on the west slope of the Cascade Mountains north of the Calapooya Mountains. We propose a hypothesis which explains the development of the current distribution pattern and the current ecological limitations placed on future spread of the parasite. The hypothesis is supported by preliminary evidence but is presented as a basis for additional experimental work aimed at demonstrating the ecological factors which influence the distribution of *A. douglasii.* We believe the parasite has been on the west slope for a long time but that its spread is limited by factor complexes correlated with such stand characteristics as canopy density and species composition.

Introduction

Arceuthobium douglasii Engelm. (Douglas-fir dwarf mistletoe) is a parasitic flowering plant which rather specifically attacks *Pseudotsuga menziesii* (Mirb.) Franco. *A. douglasii* is generally found throughout the range of its host, but it is absent in some regions (Hawksworth and Wiens, 1972); one such area is the coastal forest from central Oregon northward into Washington and the adjacent west slope of the Cascade Mountains. Exceptions to the absence of *A. douglasii* from the west slope of the Cascades became known when Wicker (1969) first reported the parasite in White Pass, Washington. Hawksworth and Wiens (1972) later reported it in the upper Clackamas River drainage in Oregon, and Tinnin and Knutson (1973) reported it in the upper North Santiam and Willamette River drainages west of the divide of the Cascade Mountains and north of the Calapooya Mountains. In all, there are nine separate locations known for the portion of Oregon within this geographic area (see Appendix). We began a study of these west slope stands, primarily studying the infection site at Sisi Butte in the Clackamas River drainage. The stand there is composed, for the most part, of *P. menziesii.* Portions of the stand are heavily infected with *A. douglasii,* but these grade into portions which are uninfected. Our goal was to determine the factors which have limited the distribution of *A. douglasii* to its present range west of the Cascade divide, and to determine the potential for the parasite to spread to currently uninfected stands.

Observations

Before *Arceuthobium douglasii* can spread along the west slope of the Cascades, it must first produce viable seeds which have available the correct host. On the western flank of Sisi Butte, we checked seed production during the summer of 1972 by tagging 459 developing fruits on 16 branches of 5 *Pseudotsuga menziesii.* These fruits were counted each month from July until early October when they were mature. At that time we collected mature seeds of *A. douglasii* and returned them to the laboratory where they were stored at 5°C over a saturated NaCl-water solution (Knutson, 1971). The germination potential of these seeds was tested 11 and 16 weeks later. The seeds were germinated in the dark (except during manipulation of solutions) by placing them in a beaker containing tap water which was maintained at 10°C for 48 hours and then into a beaker containing 4 percent H_2O_2 maintained at 15°C, with the subsequent addition of tap water to the beaker as necessary to avoid dessication, until germination occurred. The seeds were allowed to remain in the water until no further germination occurred. We found that the *A. douglasii* at Sisi Butte produced large quantities of seed which matured in 1972. Of the 459 fruits being watched, roughly 70 percent reached maturity. The seeds which we collected at this time and later tested for viability yielded 60 percent germination when first tested at week 11, and 29 percent when tested next at week 16. Individual seeds were found to germinate 2-6 weeks subsequent to treatment at 15°C; no more germinated after 6 weeks.

We looked for the youngest infected *P. menziesii* present. Whenever a small tree was found which had aerial shoots of *A. douglasii* on its branches, we cored the tree one foot above ground level. Growth rings were counted in the laboratory and the age of the tree recorded. The youngest tree found had 28 growth rings one foot above ground level. The tree was growing vigorously and so was probably about 35 years old. It should be noted that we found many small trees which were obviously broomed but which had no aerial shoots on their branches. In addition, we measured ages of another 70 trees to establish a rough age structure for the *P. menziesii* at the site. This determination of age structure showed about 65 percent of the trees were 150-200 years old, about 15 percent were 180-220 years old and about 1 percent were older than 400 years. An additional 15 percent were younger than 150 years and the remaining 4 percent filled in among the older age classes. All age classes were infected but we have not yet determined the extent of infection in each age class.

We also searched, by means of helicopter, for any current pathway of infection to Sisi Butte and nearby areas which ranged from the extensive infections on the east slope of the Oregon Cascades to the west slope. The search extended from the northern boundary of the Warm Springs Indian Reservation to Santiam Pass. We found that *A. douglasii* has, on both slopes of the mountains, a maximum elevation limit of about 1,375 m. We feel this is due primarily to a change in species composition from a contiguous stand of *P. menziesii* to a mixed stand composed largely of the higher elevation timber species. However, there are almost certainly other factors involved as well. We saw no direct pathway for the infection (*i.e.,* continuous stands of *P. menziesii* running between the east and west slopes) from the extensively infected stands east of the divide to the uninfected stands west of the divide. We did find one additional site of infection west of the divide at Pamelia Lake in the Mt. Jefferson Wilderness Area which has not been previously reported (see Appendix). The site could be considered as a subsite in the North Santiam River drainage

even though it is separated by about three air-miles (5 km) from the other known site of infection.

As we examined each of the major infection sites on the west slope of the Cascades, we found that infected stands were scattered within a matrix of healthy trees. We looked for any features which these subsites had in common which might serve to elucidate the factors limiting the western range of *A. douglasii* and to explain its present distribution. Our observations of the many subsites showed one obvious feature they held in common: each infected stand had natural openings in it. Among the factors which we found to be contributing to these openings were south facing slope exposures, ridge exposures, outcroppings of basalt, and fire and wind damage. The trees along the openings in these stands, as well as those back in the closed stands, were broomed. The openings alone do not explain the presence of the infection, but we believe them to be of key importance. We found only one case of an infection not directly associated with stands of reduced density; this was a single tree growing in a closed stand and bearing a single large, male broom. There were no other infected trees within a 100 m radius, although a large infection was within 2 km. We take this as evidence of mistletoe seed transport by birds (Zilka, 1973).

In association with the study of *A. douglasii*, we have also looked at some of the ecological characteristics of *A. tsugense* (Rosend.) G. N. Jones. We did this because, unlike *A. douglasii, A. tsugense* is widely distributed throughout western Oregon (on *Tsuga heterophylla* (Raf.) Sarg.). We were interested in noting possible differences in seed production which could exist under similar ecological conditions, for these two species of dwarf mistletoe, which might be important in explaining their respective distribution. We studied an infection on Goat Mountain in the Mt. Hood National Forest (T5S.,R4E.,sec.11). This site supports an almost pure stand of *T. heterophylla* which is relatively undisturbed. This stand is adjacent to a "clear-cut" which left many small trees standing. The *T. heterophylla* in both cases is infected with *A. tsugense.* We examined, during the summer of 1974, 20 small (1-4 m tall) *T. heterophylla* (10 in the closed stand and 10 in the adjacent open stand) to find the number of infections on each tree relative to their position on the tree, the number of aerial shoots per infection, and the approximate number of fruits produced per female aerial shoot. We thus were able to construct seed production maps for trees growing in the open as well as for trees growing in the dense shade.

Two general trends may be summarized from our investigation of *A. tsugense*: 1) the apparent vigor of *T. heterophylla* is greater in open sunlight than in shade. Associated with this, the number of infections and seeds produced by *A. tsugense* is higher on the "open sun" trees (both by at least one order of magnitude); and 2) even in very dense shade some seeds of *A. tsugense* are produced. There is no strong tendency for *A. tsugense* to be distributed unevenly around the trees in favor of a given compass direction when growing in the open sun (Table 1). This is counter to what Smith (1973) reported. The difference may be accounted for because Smith examined a single tree (our individual trees did show differences) and he studied a tree at a more northern latitude where uneven distribution may indeed exist. It was not possible for us to make the same analysis concerning the trees in the shade because they tend to grow asymmetrically. We did find that there is a differential vertical distribution of *A. tsugense* on the trees in the sun (Table 1).

TABLE 1. Number of infections as percentage of total number of infections on all trees.[1]

% Tree Height	Compass Direction					
	North	East	South	West	Total[2]	
81-100	0	0	0	0	0	a
61-80	0	0	0	1	1	ab
41-60	5	3	4	4	16	bc
21-40	13	15	8	15	51	c
0-20	8	7	11	5	31	abc
Total[3]	26	25	23	25	99	

[1] The data in this table were calculated from six of the ten trees in the open stand. These six trees were of similar shape and height. The other trees were deformed due to mistletoe infection or were shaded by other trees on one side, and thus were judged as less representative of truly open stand trees.

[2] The data in these rows are labeled according to a significant difference at the 5 percent level of confidence as determined by the STP test (Sokol and Rohlf, 1969).

[3] There is no significant difference, at the 5 percent level, among the columns.

Discussion

Our field observations and data indicate that there are a number of interacting factors which are involved in limiting the distribution of *Arceuthobium douglasii* west of the Cascade divide. However, the mistletoe is capable of spreading at the Sisi Butte site, as evidenced by the production of viable seeds which are being released at maturity and which are currently infecting trees. The question of importance is: what has confined the west slope infections to scattered stands rather than the parasite being generally distributed, as it is on the east slope of the Cascades? Our observations suggest a hypothesis in answer to this question. In part the hypothesis involves historical speculation and so in part cannot be tested. However, the important aspects can be tested. The hypothesis is as follows:

1) The parasite arrived on the west slope of the Cascades long ago. This arrival might have occurred through continuous stands of *P. menziesii* which previously existed between the east and west slopes of the Cascades, or it might have occurred by means of avian transport (Zilka, 1973).

2) Infections of *A. douglasii* were more generally distributed on the west slope of the Cascades at some previous point in time.

3) The original source of infection has ceased to exist or is of erratic occurrence allowing the infected stands to become fragmented.

4) The fragmentation occurred as a result of a) significant change in stand composition leading to the reduction in density, or exclusion of, *Pseudotsuga menzeisii*; and b) various disasters such as fire and blow-down. These factors are the historical points of the hypothesis which bring us to the situation as it currently exists.

5) The infected stands on the Clackamas and North Santiam River drainage extant today have resulted from previously infected trees which escaped the effects of changes in stand composition and of fire, wind, or other disasters.

6) The upper elevational limits of these stands are set generally by the absence of *P. menziesii*. There may also be cases where upper limits are set by environmental extremes normally associated with higher elevations.

7) The other margins of the infection are related to canopy density. The denser the canopies, the less likely it is, for whatever specific reasons, that the infections will spread. The infections are centered in relatively open stands of reduced density and therefore radiate from these centers only insofar as stand density and composition will allow.

The infections are less likely to expand in dense stands due to hindrance of seed movement and reduced seed production. These two factors interact between themselves, and among other factors (host vigor, mistletoe seedling development, and many more relating to successful infection, such that the probability of *A. douglasii* infecting an adjacent healthy tree and producing seeds there approaches zero. This point is associated with the fact that denser stands with closed canopies tend to be found on sites which gradually change in species composition from *P. menziesii* to other coniferous species if left undisturbed. The importance of this point is brought out by Smith (1972) and Wicker (1974). Because of potential instability in stand composition, great instability in potential host availability exists for any *A. douglasii* which may be present in dense, west slope stands. However, this is only a potential event at Sisi Butte since the sites we studied supported continuous stands of *P. menziesii.*

Because of the way in which dwarf mistletoe normally spreads, the infections logically would have been more general in distribution in order to establish the scattered subsites which now exist, or else animals are much more important than heretofore presumed. Animals would initially account for scattered sites of infection and those which occur in perpetually suitable microhabitats would still exist. Our search yielded no evidence of an existing source from the east slope of the Cascades. Thus, the major west slope sites are islands of infection separated by miles of healthy trees, often of non-host species. Associated with this geographical phenomenon, each major site of infection is observed to be composed of several subsites. We can only speculate as to the causes of fragmentation; however, we found ample evidence of fire and blow-down. The infection sites which remain are consistently associated with rocky outcrops or deep canyons which could have protected small groups of trees from damage by fire. The upper elevational limits of *A. douglasii* are correlated with the transition to tree species other than *P. menziesii*; nonetheless, the upper limits of some species of dwarf mistletoe are apparently set by factors such as those mentioned in point six of the hypothesis (Williams, Fortier, and Osborn, 1972) and there is no reason to believe that *A. douglasii* responds otherwise. As judged from the air, the infection sites are surrounded by denser stands of trees. It is, at this time, not possible to say whether the infected stands are less dense because of the infection or are prone to infection because they are less dense. Regardless of the case, we speculate, based on some preliminary seed counts and observations, that reduced seed production on *P. menziesii* is correlated with increased canopy density. Whatever the specific cause of this reduction, the proposed correlation helps explain the present limitations of distribution observed in west slope *A. douglasii.*

Since we have postulated that the west slope range of *A. douglasii* has been determined by disasters such as fire and a complex of factors presently interpreted as canopy density, we must assume that fire and perhaps canopy density would be equally involved in affecting other species of *Arceuthobium. A. tsugense* is very widespread west of the Cascade Mountain divide, where it is parasitic primarily on *Tsuga heterophylla.*

One may question the difference in distribution between *A. tsugense* and *A. douglasii* as related to our hypothesis. We feel that several factors have interacted to allow the wide distribution of *A. tsugense*. We know that both species of *Arceuthobium* produce seeds in very dense shade but we also know that *T. heterophylla* grows better in the shade. Thus, in a given shaded environment, *T. heterophylla* will show greater vigor than *P. menziesii*. This should allow greater seed production by the *A. tsugense* at the same time more vigorous hosts are available to the parasites. Even if a stand of *T. heterophylla* burns, we would expect long range stability for the parasite in the regenerating stands. Any reduction in range due to fire could, in the case of *A. tsugense,* be negated by the more effective production of seeds by *A. tsugense* and more consistent host availability in the dense west slope forests. Fire would, therefore, have a lesser influence on the distribution of *A. tsugense.*

If our hypothesis is correct, the infection of *A. douglasii* on the west slope of the Cascades represents relict occurrences of the parasite. Nonetheless, the infection retains the potential to spread, given proper environmental conditions. Some of these conditions may well be provided by man's current active manipulation of the forest.

Appendix

We have now observed *Arceuthobium douglasii* at one site west of the Cascade Mountain divide in Mt. Hood National Forest and at eight such sites in the Willamette National Forest. Each of these sites lies north of the Calapooya Mountains. South of these mountains, infections of *A. douglasii* are relatively common and well documented (Hawksworth and Wiens, 1972). The location of each of the sites is approximately as follows:

Mt. Hood National Forest:
- Sisi Butte:
  - T.8S., R.7E., sec. 2,11-14, 24.
  - T.7S., R.8E., sec. 28,29,31-33.
  - T.8S., R.8E., sec. 5-8,16-18.

Willamette National Forest:
- Pamelia Lake:
  - T.10S., R.8E., sec. 32-38.
  - T.11S., R.7½E., sec. 1.
  - T.11S., R.8E., sec. 6.
- North Santiam River:
  - T.11S., R.7E., sec. 13,14,23-25.
- Black Creek:
  - T.21S., R.5E., sec. 14,15,23,26,27.
- Swift Creek:
  - T.23S., R.5E., sec. 28,31,32.
- Echo Creek:
  - T.24S., R.4E., sec. 22,23,26,27.
- Spider Creek:
  - T.24S., R.4E., sec. 33.
- Youngs Creek:
  - T.23S., R.3E., sec. 36.
- Buck Creek:
  - T.23S., R.3E., sec. 12.

The actual extent of each of these infections has never been surveyed, to our knowledge, so the section numbers listed above are only to provide approximate locations.

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Potential Avian Influence in the Distribution of Dwarf Mistletoe[1]

Abstract

Our goal was to study the potential of birds as vectors for the movement of dwarf mistletoe seeds and the means by which such movement could occur. Seed movement by birds would greatly speed the rate at which dwarf mistletoe moves through the forest. Five areas in Oregon, heavily infected by various species of *Arceuthobium*, were studied. Observations of avian behavior point to 10 species whose general behavior make them high potential vectors in the distribution of these parasites. More specifically, the roosting and subsequent bathing behavior of many forest birds provides a very important means of potential seed transport. Additionally, an examination of nesting materials revealed that birds bring viable dwarf mistletoe seeds to infectible parts of host trees during the construction of their nests. However, nesting seems the least important of the vector mechanisms discussed. No birds were observed feeding on the seeds of dwarf mistletoe, nor were seeds found in their droppings. More probably seeds are carried externally on the birds.

Introduction

Arceuthobium spp. (dwarf mistletoe) causes considerable economic loss to coniferous forests in the New World. Childs and Shea (1967) estimate that approximately 147.5 million cubic feet of wood are lost annually in Oregon and Washington because of *Arceuthobium*. Because of this large loss, many of the silvicultural practices used in mistletoe infested regions are designed to limit the spread of this parasite. Clear-cutting is considered the best available method of control, although other methods of sanitation are also applied, particularly in areas where clear-cutting is unfeasible. Since dwarf mistletoe is estimated to disperse through a stand at approximately 0.3-0.6 m/yr (Hawksworth, 1961) by means of its explosive mechanism of seed dispersal, reinfection of sanitized stands should be relatively slow. Animals represent a potential vector for much more rapid movements of seeds through such stands.

Birds have long been recognized as real or potential carriers of dwarf mistletoe seeds. Birds are often considered when infections on islands are discussed (Hawksworth and Wiens, 1972). Hawksworth and Wiens (1972) also discuss the very rapid northern migration of *Arceuthobium* in North America since the pleistocene glaciation. With the recession of the ice and subsequent reforestation, one could expect (using the 0.6 m/yr lateral dispersal rate) *Arceuthobium* to have moved about 6 km in 10,000 years. In fact, the parasite has moved much farther northward during that time at an approximate rate of 160 m/yr. The investigation reported here was concentrated on short range dispersal which has as one of its most important implications the relatively rapid reinfection of a portion of a stand cleared of the parasite.

[1] This work was conducted by Mr. Zilka in partial fulfillment of the requirements for the Master of Science degree. Present address: Department of Environmental Quality, Northwest Region, 1010 N. E. Couch Street, Portland, Oregon 97232.

In connection with localized seed movements, we wanted to study which species of birds, because of their habits, have the greatest potential for spreading dwarf mistletoe seeds; and by what means such transport most likely occurs.

Methods and Materials

The major part of this research was conducted from July 1972 to May 1973. The initial work involved locating areas of heavy infection. Three major areas and two supplemental areas were chosen. Priorities for the choices were: (1) stands heavily infected by species of *Arceuthobium*; (2) stands containing several host-parasite species combinations (Table 1); and (3) relatively open areas so that bird observations

TABLE 1. Host-parasite species combination studied at each site.

Observation Area	Host Species	Species of *Arceuthobium*[1]
Site 1	*Pinus ponderosa*	*A. campylopodum*
	Pseudotsuga menziesii	*A. douglasii*
Camp Sherman	*Larix occidentalis*	*A. laricis*
	Abies grandis	*A. abietinum*
Site 2	*Pinus ponderosa*	*A. campylopodum*
	Pseudotsuga menziesii	*A. douglasii*
Maury Mountains	*Larix occidentalis*	*A. laricis*
	Abies grandis	*A. abietinum*
Site 3	*Pinus ponderosa*	*A. campylopodum*
	Pseudotsuga menziesii	*A. douglasii*
Summit Prairie	*Larix occidentalis*	*A. laricis*
	Pinus contorta	*A. americanum*
Site 4	*Pseudotsuga menziesii*	*A. douglasii*
	Pinus ponderosa	*A. campylopodum*
Badger Area	*Larix occidentalis*	*A. laricis*
	Abies grandis	*A. abietinum*
Site 5	*Tsuga heterophylla*	*A. tsugense*
Dodge Area		

[1] The species of *Arceuthobium* are named according to Hawksworth and Wiens (1972) and are listed according to frequency of occurrence at each site.

were not seriously hampered. The areas found which fit these criteria were: Site 1, Camp Sherman in the Deschutes National Forest; Site 2, the Maury Mountains in the Ochoco National Forest; Site 3, Summit Prairie in the Ochoco National Forest; Site 4, the Badger area in the Mt. Hood National Forest; and Site 5, the Dodge area in the Mt. Hood National Forest.

The research was conducted in three parts: (1) observation of birds in the field during late summer and early fall, the season of dwarf mistletoe seed release; (2) winter observation of birds at feeders supplied with dwarf mistletoe seeds; and (3) spring census of nesting birds and their nests looking for dwarf mistletoe seeds which had been carried on nesting materials into infectible parts of trees.

The field observations were aided by the use of Bushnell binoculars (7 x 35) and a Bushnell spotting scope (20-45X) and identification was facilitated by the use of standard reference books (Robbins, *et al.*, 1966; Peterson, 1941; Gabrielson and Jewett, 1940). Birds were captured with the use of a mist net (for smaller passerines) and 130 x 130 x 410 cm National Live Traps. Observations of bird activity at feeders was accomplished at Zilka's home over the winter of 1972-73. *A. campylopodum*

and *A. tsugense* seeds were supplied along with commercial bird seed and suet. Nesting materials were collected from Sites 1, 2, and 5 during the spring and summer of 1973, some of which dated back to the 1972 breeding season.

Results and Discussion

For a bird to transport dwarf mistletoe seeds effectively, several important conditions must be met: (1) the seed must become attached to the bird, or be ingested. Mistletoe seeds are very sticky for a time after being discharged from the fruit. This time period varies from minutes to a day or more depending upon such environmental factors as humidity, temperature, and exposure to wind. Any animal hit by a discharged seed, or that otherwise comes in contact with a moist seed, could become a vector in the distribution of dwarf mistletoe; (2) all female seeds must land within reasonable proximity of a male infection to facilitate pollination and establish seed production; (3) the seed must arrive in viable condition on a potential host; (4) the seed must be introduced to the younger parts of a host limb, if infection is to be realized. Each of these points was considered when making and interpreting field observations.

Field observation during period of seed dispersal. A list of birds found in dwarf mistletoe-infected trees during times of seed discharge has been compiled (Zilka, 1973). To each species on the list we have ascribed numbers which reflect its potential to act as a vector in the spread of dwarf mistletoe. Two basic components were evaluated to determine this potential. First, habitat priorities were estimated by observing the amount of time individuals of a species spent in infected or infectible trees; these priorities are an expression of the potential of each species to pick up and transport mistletoe seeds relative to the total amount of time each species was observed. Second, frequencies of occurrence of each species were related to the number of individuals of the most frequently observed species, the Red-breasted Nuthatch. Each frequency is expressed as a whole number between one and 100, with the Red-breasted Nuthatch being 100. This frequency scale is inaccurate for values less than 20 and so, for birds species with frequencies less than 20, frequency is not reported. To estimate the potential for a bird species to serve as a vector for dwarf mistletoes, the habitat priority and frequency of occurrence factors were multiplied together. The higher the resulting value the higher the species' potential for moving seeds. Generally, we regard species with a vector potential value greater than 100 as likely to be important in the transport of dwarf mistletoe seeds.

Although 80 species of birds were observed, those which we believe to be most important vectors of seed movement are listed (Table 2). The four members of the

TABLE 2. Species commonly found in infected and infectible trees.

Species[1]	Region Observed[2]	Habitat Preference[3]	Frequency[4]	Vector Potential[5]
Red-breasted Nuthatch— *Sitta canadensis*	E, W	5	100	500
White-breasted Nuthatch— *Sitta carolinensis*	E, W	5	90	450
Black-capped Chickadee— *Parus atricapillus*	E, W	5	90	450
Mountain Chickadee— *Parus gambeli*	E	5	90	450

Pine Siskin— *Spinus pinus*	E, W	5	70	350
Evening Grosbeak— *Hesperiphona vespertina*	E, W	5	60	300
Steller's Jay— *Cyanocitta stelleri*	E, W	5	50	250
Hairy Woodpecker— *Dendrocopos villosus*	E	4	40	160[6]
Dark-eyed Junco— *Junco hyemalis oreganus*	E, W	3	50	150[6]
American Robin— *Turdus migratorius*	E, W	3	50	150[6]
Gray Jay— *Perisoreus canadensis*	E	5	20	100
Common Flicker— *Colaptes auratus*	E,W	4	25	100[6]
Red Crossbill— *Loxia curvirostra*	E	5	20	100
Western Bluebird— *Sialia mexicana*	E	3	30	90
American Goldfinch— *Spinus tristis*	E	3	30	90
Yellow-rumped Warbler— *Dendroica coronata auduboni*	E	4	20	80
Downy Woodpecker— *Dendrocopos pubescens*	E, W	4	20	80
Townsend's Solitaire— *Myadestes townsendi*	E	4	20	80
Chipping Sparrow— *Spizella passerina*	E, W	3	20	60
Rufous-sided Towhee— *Pipilo erythrophthalmus*	E, W	3	20	60
Lesser Goldfinch— *Spinus psaltria*	E	3	20	60
Bushtit— *Psaltriparus minimus*	W	5	—	—[7]
Pigmy Nuthatch— *Sita pygmaea*	E	5	—	—[7]
Clark's Nutcracker— *Nucifraga columbiana*	E	5	—	—[7]
Brown Creeper— *Certhia familiaris*	E	5	—	—[7]

[1] The names are corrected according to Tate and Kibbe (1974).

[2] "E" means east slope sites 1, 2, 3, and 4; "W" means west slope site 5.

[3] Habitat values reflect the percentage of time these species spent in infected and infectible trees. A value of 5 means that of the total time the species was observed, 81-100 percent of that time the birds were in host trees. A value of 4 means 61-80 percent, 3 means 41-60 percent, 2 means 21-40 percent, and 1 means 1-20 percent.

[4] Frequency values are based upon the number of observations of the species in question relative to the total number of Red-breasted Nuthatch observations. During the period of August through October 1972, Zilka recorded seeing 280 Red-breasted Nuthatches. These sightings ranged in duration from a matter of seconds to approximately one hour.

[5] Vector Potential = Habitat Preference X Frequency, and is an estimate of potential for a species to move seeds of dwarf mistletoe; large numbers meaning greater potential.

[6] Although the species have a high Vector Potential, they are not considered as high potential spreaders of *Arceuthobium* seeds as a result of their overall behavior.

[7] Vector Potentials for birds with a Frequency less than 20 have not been calculated as a result of the inaccuracy of those data.

closely related families Paridae and Sittidae are the most important of these. These four species often form flocks of ten or more individuals when feeding. Frequently the Red-breasted Nuthatch and the Mountain Chickadee occurred together, and the White-breasted Nuthatch and the Black-capped Chickadee occurred together. Often kinglets, creepers, and bushtits accompany these flocks. These groups fly from tree to tree hunting insects. They search through whole trees but spend a significant amount of time in the youngest thus most infectible parts of trees. Flocks of these birds were often observed in mixed infected stands which included such species as *Abies grandis, Larix occidentalis, Pinus ponderosa,* or *Pseudotsuga menziesii.* The whole flock would begin hunting in three or four trees and then slowly break up into groups of one, two, or three individuals as it moved through the forest. The net movement resulted in the flock feeding in many but not all of the trees encountered in the area. After 20 to 30 minutes the whole flock would take off in unison and fly 100 m or more and begin feeding in a new group of trees. The new feeding area looked no different from that which the birds had just left, or the area they passed by. No preference by these flocks was detected for a particular tree species, or for trees infected by or free of dwarf mistletoe.

The habits of the Steller's Jay make it particularly important as a potential vector for mistletoe transport. This species is gregarious and spends most of its time in flocks which moved through the forest hunting food. Generally, when the birds are in the lower parts of the tree they prefer perches, often dead limbs, near the main stem of the tree. As they move up the tree to the top, they land in younger, more infectible parts of the tree. The birds then fly to the lower branches of the next tree and move eventually to its top, and so on from tree to tree. When they are not actively hunting, they often spend time in the highest perches watching and preening. These regions of the conifers are highly infectible as a result of their young age and, once infected, they have a greater potential for establishing new infections in the surrounding trees.

Although the Red Crossbill is difficult to observe because it feeds almost exclusively in the canopy of the tallest conifers, Zilka has seen crossbills high in the tops of infected trees apparently reacting to being hit by discharged seeds. The observed behavior patterns could have resulted from several different stimuli, but some support is given to this interpretation in that one bird was observed to land and begin preening its feathers and wiping its bill on a canopy limb.

Observations of birds in hemlock forests west of the Cascade divide were limited in comparison to work in the east slope forests. However, potential carriers of dwarf mistletoe seeds were seen. The most likely of these were the Bushtit, the Black-capped Chickadee, and the White-breasted Nuthatch. Although Bushtits are very similar to other members of the Paridae already discussed, there are several distinctive aspects of their behavior that should be noted. They are considerably smaller than the chickadees and nuthatches with which they commonly flock. Consequently, they spend much time in the youngest parts of the trees (increasing their potential as vectors). They are common in stands of young trees and in newly regenerated areas. Their flocks are much tighter and consist of more individuals than those of the other members of the paridae observed. Groups of 15 or 20 individuals were commonly seen and heard in a single young tree.

Members of the families Tetraonidae and Columbidae could be much more important in the distribution of dwarf mistletoe than one might expect of large birds.

They often perch and preen on the leader of trees such as *Tsuga heterophylla.* This is particularly important since grouse are reported to feed on aerial parts of dwarf mistletoe during the fall (Wagner, 1968; Weir, 1916b).

Of the 10 birds species listed as likely distributors of dwarf mistletoe in Oregon, most are permanent residents of the coniferous forests. Those of the family Paridae are known to migrate south occasionally, particularly during unusually severe winters; but generally they remain in the forest throughout the winter and migrate down slope (in any compass direction) with colder weather. A common argument against movement of dwarf mistletoe seeds by birds is that bird migration patterns are such that they would constitute an influence only on the southward movement of the parasite. For example, migratory forest passerines might be responsible for the distribution of *A. douglasii* in southern Oregon and northern California. *A. douglasii* is found primarily on the east side of the Cascade divide in Washington and Oregon, but ranges near the coast in southern Oregon and northern California (Hawksworth and Wiens, 1972). This reflects the route that a number of migratory bird species appear to follow (Dorst, 1962). Obviously, the restriction to only southward movement of seeds does not apply to permanent residents of the Northwest, since they move locally throughout the forest in the fall. They have only to move the seeds 6 m/yr to increase the estimated rate of spread of dwarf mistletoe by one order of magnitude. In fact, birds could be routinely carrying and depositing the seeds at much greater distances from their source.

Avian hygenic habits may be the single most important factor in short range epizoochory of dwarf mistletoe. Most of the species observed frequently choose brooms for night perches. Probably a bird perched in a broom through several hours of darkness would be hit by seeds or would pick them up on its feet. Further, most passerines bathed in a dew source in the early morning. After wetting themselves, they flew to high perches and sat in the sun to preen and dry their feathers. The whole process is often completed within several 100 m of the previous night's perch.

Observations show that birds do pick up seeds of dwarf mistletoe, probably as a result of being hit by discharged seeds (Zilka observed 28 instances, in 350 hrs of observation, which he interpreted as cases of birds being hit by seeds); or by contact with already discharged seeds which are on the ground or in the trees. During a brief collection period in the fall of 1973, 18 birds representing 11 species were collected. Four of these birds had seeds in their feathers. The birds with seeds were a Cassin's Finch, a Mountain Chickadee, a Red Crossbill (2 seeds), and a Steller's Jay. Additional birds collected were a Black-capped Chickadee, three Mountain Chickadees, two Dark-eyed Juncos, a Red Crossbill, an American Robin, a Golden-crowned Kinglet, a Ruby-crowned Kinglet, a Steller's Jay, two Townsend's Solitaires, and a Winter Wren. Each of the seeds found was in good condition and was firmly attached to the feathers. The birds probably would have had to wet the seeds (as during bathing) to remove them.

The observations of Hawksworth (1961) and Weir (1916a, 1916b) illustrate feeding as a possible means of dispersal. Hawksworth mentions he once saw Evening Grosbeaks feeding on aerial parts of *A. campylopodum* and found voided seeds in their and other droppings. He stated that feeding on dwarf mistletoe is not rare, but viability of voided seeds is likely to be very low. During the four-month period of field study, no birds were observed feeding on dwarf mistletoe seeds or fruits or

aerial shoots. In addition, no seeds of dwarf mistletoe were seen in the hundreds of bird droppings checked in the field. This agrees with the observations of Baldwin (personal communication) who, after examining the stomach contents of approximately 150 forest passerines collected from the forests around Ft. Collins, Colorado, wrote: "I have looked at most of this material, in addition to large numbers of stomach samples of woodpeckers and numerous passerines. Although alerted to the mistletoe (*Arceuthobium*) dispersal problem, I have yet to recognize a mistletoe seed in any bird stomach sample."

Feeder observations. Although dwarf mistletoe seeds were available at a bird feeder for almost two months during the winter, during which time two dozen species of birds visited the feeder, no bird was seen to feed on the seeds. However, over that period of time the dwarf mistletoe seeds did disappear. A total of 320 seeds were placed at the feeder over the two-month period. Probably most of them were kicked to the ground by birds and squirrels or washed away by rain. By spring a number of seeds were still on the ground around the feeder. One seed was found on a young hemlock tree about twenty feet from the feeder. The only source of seeds was from the feeder.

Seeds on nesting materials. We found that forest passerines do bring viable seeds to their nesting sites. There are a large number of seeds available on the ground in the fall but we found that most of these seeds are gone or are not viable by spring. The result is that, even though birds use materials collected from the forest floor for nesting, most of these are free of dwarf mistletoe seeds. On the other hand, mosses and foliose lichens are an excellent reservoir for dwarf mistletoe seeds. The seeds seem to over-winter on these plants with the result that the seeds are viable when the nesting season begins in the spring. There are several species of birds which are known to nest in Oregon, frequent forested areas, nest in the infectible part of host trees, and use materials for nesting that are likely to contain dwarf mistletoe seeds. We are aware of 43 species which meet all of these conditions (Gabrielson and Jewett, 1940; Wetmore, 1964). Of these, 17 species typically use moss and/or lichens among the materials they use for nest construction.

Seven nests were collected during the spring and summer of 1973 and five had dwarf mistletoe seeds on them. Most commonly, these seeds appeared to have been taken to the nest on lichens or moss material used in construction. The five nests that contained seeds all had lichens, mosses, or both in them. The other two nests were devoid of lichens and mosses; they were made of dry grasses in one case and sticks and twigs in the other.

On the nest of a Western Flycatcher were three viable seeds that had formed holdfasts on nesting materials. On an active nest of a Hammond's Flycatcher were four seeds. On the same day, three seeds were collected from lichens on trees in the same area. None of these seeds had germinated. At the laboratory, we placed them in 2 percent H_2O_2 in the dark at 15 C. After two weeks three of the seeds from the nest had succumbed to fungal growth while one had germinated. All of the seeds from the lichens germinated. These seeds were placed on a young Ponderosa pine and two of the seeds formed holdfasts.

In coniferous forests of the Northwest, many species of birds prefer young trees

where they usually build their nests less than 3 m from the ground in the bushiest part of the tree, or they prefer the canopy of the forest, often nesting in a broom. Those birds nesting in brooms do not, so far as transport of seeds on nest materials is concerned, aid in the dispersal of dwarf mistletoe. Nests in young trees, however, especially in the regrowth of clear-cut areas, could constitute an important source of infection. It only takes one female infection located centrally on young regrowth of a clear-cut to reduce greatly the potential yield when a long rotation time is being followed.

Summary and Conclusions

Our observations confirm the statements of several authors that birds have an important potential role in the distribution of dwarf mistletoes. Our observations point to three likely means of seed movement of which the daily bathing behavior of birds is, in our opinion, the most important, followed by other daily activities of specific birds, and then by nesting activities. The bathing habits of most forest birds are such that almost any species could carry dwarf mistletoe seeds to uninfected trees. However, with respect to other daily activities, 10 avian species are listed whose frequency of occurrence and behavior imply a significant role in seed transport. Individuals of some of these species were collected and we found seeds stuck to their feathers. The nesting habits of birds are of potential importance because of the large number of species which could carry viable dwarf mistletoe seeds back to younger parts of host trees. No cases where birds ate or voided viable seeds were noted.

Because of the low level of successful establishment by seeds of dwarf mistletoe, birds would have to carry and deposit a large number of seeds to be an effective means of spreading the parasite. Such is probably not the case. Nevertheless, even infrequent transport could lead to scattered sites of infection which would frustrate otherwise effective control measures.

The important question—What quantity of new infections occur as a result of avian activity?—remains unanswered. The economic significance of dwarf mistletoe damage to the multimillion dollar timber industry is extremely great. Hence, the degree of bird involvement with the spread of this parasite should be more precisely documented.

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Estimating Ages of Cottontails by Periosteal Zonations

Abstract

Mandibles from 78 eastern cottontails (*Sylvilagus floridanus*) and 58 Nuttall's cottontails (*S. nuttallii*) were decalcified, cross-sectioned, stained, and examined under the microscope. Densely stained lines in the periostal zone were absent in 64 (98.5%) of 65 mandibles from cottontails whose lens-weights, unossified epiphyseal cartilages, or known ages indicated that they were young-of-the-year. One or more densely stained lines were present in mandibles from 68 (95.8%) of 71 cottontails for which there was corroborating evidence that they were 1 year old or older. The periosteal zonation technique appears to be useful for separation of age classes among the adult cohort of cottontail populations, but provides no particular advantage over the lens-weight technique for separating adults from young-of-the-year. Use of the two techniques in combination provides a means by which age structures of cottontail populations can be established more precisely than heretofore possible.

Introduction

This is a report on the determination of ages of eastern and Nuttall's cottontails (*Sylvilagus floridanus* and *S. nuttallii*) from densely stained lines ("adhesion lines") in the mandibular periosteum.

Ages of cottontails are commonly estimated by the degree of ossification between the epiphysis and diaphysis of long bones (Thomsen and Mortensen, 1946; Hale, 1949; Petrides, 1951) and from the weight of the dried lens of the eye (Lord, 1959). Lens-weight reportedly is more reliable than ossification of the epiphyseal cartilage for separating adults from young-of-the-year (Wight and Conaway, 1962; Edwards, 1962; Rongstad, 1966). However, Edwards (1962), Rongstad (1966), and Friend (1968) considered the lens technique to be unreliable for separating year classes of cottontails older than 1 year. Klevezal' and Kleinenberg (1967) reported the occurrence of adhesion lines between annual layers of bone deposited in the periosteal zone of mandibles of Asiatic pikas (Ochotonidae) and other mammals. Millar and Zwickel (1972) used these adhesion lines to estimate ages of North American pikas (*Ochotona princeps*). We wished to determine if the technique were applicable to other lagomorphs.

Methods and Materials

Seventy-eight eastern cottontails were collected on the E. E. Wilson Game Management Area about 11.5 km north of Corvallis, Benton County, Oregon, between 23 August and 30 September 1973. These dates were chosen because the oldest eastern cotton-

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tail born in 1973 was expected to be less than 7 months old at this time (Trethewey and Verts, 1971); consequently, this group could be distinguished from adults on the basis of ossification of the epiphyseal cartilages of their radii and ulnae (Hale, 1949). Twenty-five Nuttall's cottontails were collected between 11 September and 11 October 1973, about 4.9 km west of Terrebonne, Deschutes County, Oregon; the oldest individual born in 1973 in this collection was expected to be less than 6 months old (Powers and Verts, 1971). Presumably, these juveniles also could be distinguished from adults by unossified epiphyseal cartilages in the bones of their forelegs. An additional 15 Nuttall's cottontails were collected in the same area between 1 April and 14 June 1972 (a period during which adults were distinguished from juveniles by size and reproductive status), and 18 more were collected at irregular times during 1972 and 1973. Of the 58 Nuttall's cottontails, 27 were recoveries of individuals marked as juveniles and 5 marked as adults, providing a sample for which a maximum or minimum age was known.

Cottontails were returned to the laboratory where both eyes, one radius and ulna, one humerus, and the mandibles were collected from each individual. Eyes were preserved in 10 percent Formalin for at least 30 days (Friend, 1968). Lenses were removed, dried for 7 days at 80° C, and weighed to the nearest 1.0 mg. Radii, ulnae, and humeri were cleaned in a 25 percent solution of laundry bleach (Clorox), and were examined to determine the degree of ossification of the epiphyseal cartilages. Mandibles were decalcified in a 5 percent solution of 67 percent nitric acid for about 12 hours (until bone and teeth were flexible), and rinsed in running water for 12 hours. The diastema portion was removed, dehydrated in a graded series of alcohol solutions, infiltrated with paraffin, and embedded in paraffin (Humason, 1967). Embedded tissues were cross-sectioned at 11 μ, mounted on slides with Mayer's albumen, and stained with Papanicoloau (Harris) hematoxylin. Slides were examined under the microscope for the presence or absence of dark stained lines in the periosteum (Fig. 1).

Counting the densely stained lines and assigning individuals to age classes was usually straightforward. However, branching of adhesion lines in mandibles of some individuals required that several sections be examined and that each line be traced to insure that it did not terminate as a side branch rather than continue the full length of the section. We commonly found adhesion lines to be more distinct and more easily counted on the labial and ventral sides of the mandibles. "Lines of resorption" between the periosteum and mesosteum (Klevezal' and Kleinenberg, 1967) were visible in some sections, but usually could be separated easily from adhesion lines because they were relatively deeper in the bone, and because they tended to be irregular rather than parallel to the periphery of the mandible (Fig. 1).

We attempted to expedite the process by sectioning the decalcified mandibles with a freezing microtome, but cottontail mandibles were so cancellous that sections fragmented badly. Also, we sectioned portions of the mandible beneath the row of cheek teeth and from the angle of the jaw of some individuals in an attempt to locate areas in which branching of adhesion lines was somewhat less than in the diastema. No particular advantage in using these portions was noted, and the diastema was easier to embed and section. Adhesion lines were visible in cross sections of humeri, but were not separated sufficiently to permit counting them easily.

Results and Discussion

One or more adhesion lines were present in mandibles from 68 (95.8%) of 71 cottontails for which there was corroborating evidence that they were 1 year old or older. Among Nuttall's cottontails for which approximate ages were known and in the sample of eastern cottontails there was complete agreement between ages determined by lens-

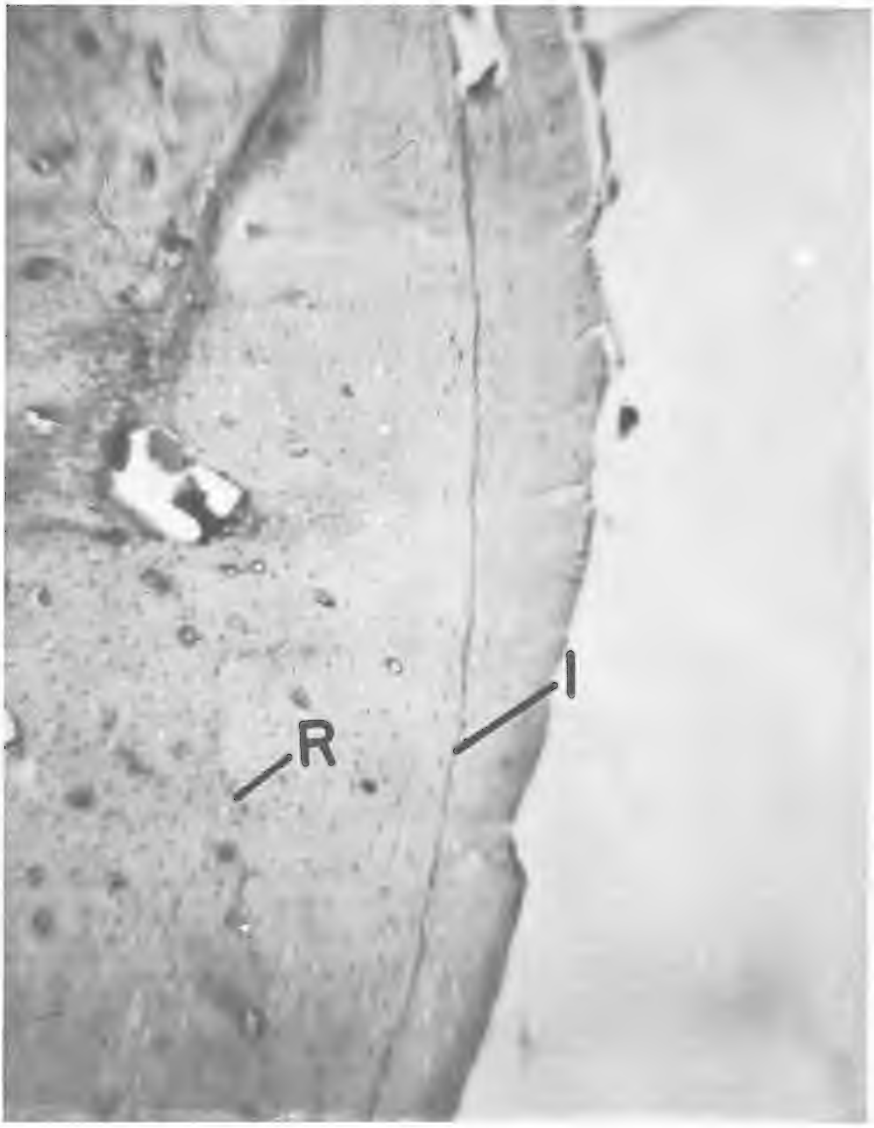

Figure 1. Photomicrograph of a cross section through the diastema of the mandible of an eastern cottontail showing one adhesion line in the periosteal zone (1). Note difference between adhesion line and resorption line (R).

weight, ossification of epiphyseal cartilages, and periosteal zonation methods (Tables 1 and 2). In these samples, no adhesion lines were visible in sections of mandibles of individuals in which ossification of epiphyseal cartilages was complete, which had lens-weights indicating that they were young-of-the-year, or which a minimum known age indicated that they were young-of-the-year. Conversely, one or more adhesion lines was present in sections of mandibles of all individuals in these samples for which there was corroborating evidence that they were 1 year old or older. One female marked as an adult on 13 July 1972, and killed on 19 September 1973 (thus, at least 780 days old), had three adhesion lines indicating that it was born in 1970, and was 2 years old when marked. Four other adults known to be at least 407 days old when killed all had more than one adhesion line: two had one line, one had two lines, and one had three lines (Table 1).

Among 26 unmarked Nuttall's cottontails for which no maximum or minimum age was known, three adults collected in April had no visible adhesion lines in sections of their mandibles (Table 2). Because the first litter of Nuttall's cottontails is usually born about 1 April in central Oregon (Powers and Verts, 1971), there is no possibility that these individuals were misclassified. Formation of densely staining lines may be occurring at this season among young-of-the-previous-year, perhaps in response to the onset of the reproductive season. A female collected on 12 September 1973, whose lens-weight and unossified epiphyseal cartilages indicated that it was born in 1973 (Table 2) had a distinct adhesion line in sections of its mandible. We are not able to offer a plausible explanation for this exception.

Because we did not collect cottontails between mid-October and April, we are not certain when adhesion lines were formed in cottontail mandibles. It appeared that formation of lines occurred sufficiently late to permit use of the technique at least through mid-October, but whether the technique could be used to determine ages of cottontails collected during hunting seasons that extend through December and beyond is unknown. We speculate that formation of the lines occurs at different times in different regions, requiring that the time of formation be established locally if the periosteal zonation technique is to be used with specimens collected in late autumn and winter.

The high rate of agreement between the different methods of estimating age, the

TABLE 1. Numbers of marked Nuttall's cottontails with ossified and unossified epiphyseal cartilages and numbers with 0, 1, 2, and 3 adhesion lines in sections of their mandibles, grouped by maximum and/or minimum lens-weight and age. Specimens were collected in 1972-73 in Deschutes County, Oregon.

Age when marked[1]	Year marked	Weight of lens (mg)	Age when killed (days)	Epiphyseal cartilage				Number of adhesion lines			
				Radius & ulna		Humerus					
				Open	Closed	Open	Closed	0	1	2	3
Juvenile	1972-73	<150	<177	21	3	24	0	24	0	0	0
Juvenile	1972	201-225[2]	383-537	0	3	0	2[3]	0	3	0	0
Adult	1973	220-250	>407	0	4	0	4	0	2	1	1
Adult	1972	219	>780	0	1	0	1	0	0	0	1

[1] Based on size and reproductive status.
[2] No lens available for one specimen.
[3] One sample not suitable for determination.

TABLE 2. Numbers of each of two species of cottontails with ossified and unossified epiphyseal cartilages, and numbers with 0, 1, 2, and 3 ahesion lines grouped by age based on the dry weight of the lens.

Species	Weight of lens (mg)	Age (days)[1]	Epiphyseal cartilage				Number of adhesion lines			
			Radius & ulna		Humerus					
			Open	Closed	Open	Closed	0	1	2	3
Sylvilagus nuttallii	<150	<177	4[2]	0	5	0	4	1	0	0
Sylvilagus nuttallii	>177[3]	>291	0	20[2]	0	19[4]	3	13	4	1
Sylvilagus floridanus	<168	<220	36	0	36	0	36	0	0	0
Sylvilagus floridanus	>185	>269	0	42	0	42	0	23	16	3

[1] Estimated on the basis of lens-weight.
[2] One sample not suitable for determination.
[3] No lenses available for two specimens.
[4] Two samples not suitable for determination.

gradual decline in numbers of individuals in older age classes, and the absence of cottontail rabbits with more than three adhesion lines in the periosteum tends to indicate that the periosteal zonation technique will be useful for separating year classes among cottontail populations. Because the lens-weight technique appears to be reliable, and considerably more expeditious to use, we do not advocate use of the periosteal zonation technique for separating adult cottontails from young-of-the-year. However, use of the two techniques in combination appears to provide a means by which age structures of cottontail populations can be established more precisely than heretofore possible.

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A Survey of the Bottom Fauna of Lake Sammamish

Abstract

The horizontal and vertical distribution of the bottom fauna in Lake Sammamish, Washington, is described. The species composition reflects the mesotrophic character of the lake. Local enrichment is indicated by higher oligochaete abundance and fewer chironomid species near the main inlets. Oligochaetes and chironomids are more abundant than in the nearby mesotrophic-oligotrophic Lake Washington. Subfossil chironomids support previous evidence that the lake was also mesotrophic before the arrival of European man. The extremely high abundance of *Chironomus atritibia* in the deep profundal even during periods of anoxic conditions suggests that nutrient factors are more important than oxygen in regulating the composition of profundal chironomid communities in general.

Introduction

This paper deals with the general features of the bottom fauna in Lake Sammamish, Washington, based on the results of a survey made in July 1974 (Fig. 1). The composition and distribution throughout the lake and in the sediments are used to indicate the present and earlier trophic state and effects of watershed development. Lake Sammamish bottom fauna is compared with data from other Lake Washington watershed lakes reported by Thut (1965) and Bissonnette (1974).

Study Area

Lake Sammamish lies about 20 km east of Seattle, Washington. The lake has a moderate depth and area, and can be characterized as mesotrophic with respect to phytoplankton productivity and biomass, and mesotrophic-eutrophic with respect to concentrations and loadings of phosphorus and nitrogen and oxygen deficit. During the late summer, hypolimnetic oxygen is near zero. Various aspects on the limnology of the lake have been treated by Taub, *et al.* (1972), Welch, *et al.* (1972), Hendrey (1973), Rock (1974), and Welch, *et al.* (1975). Some pertinent limnological data are summarized in Table 1.

TABLE 1. Some limnological data on Lake Sammamish.

Area (km^2)	19.8
Volume (km^3)	0.35
Maximum depth (m)	31
Mean depth (m)	18
Flushing rate (year)	2.2
Annual total P supply (kg)	13,000
Chlorophyll *a* ($\mu g/1$, growth season)	7.0
Primary productivity (mg C/m^2 day, growth season)	770

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Methods and Materials

Samples were taken with an Ekman sampler in July 1974 at nine stations at 5, 15, and 25 m depths (Fig. 1). The bottom material was sifted through a net with a mesh size of 0.4 mm. The remainder was preserved in 70 percent ethanol for later analysis in the laboratory. Three to five sample units were taken at each station. Because of the large amount of coarse debris in the bottom at some stations, particularly the shallow ones, it was not possible to process all the material. Therefore, as indicated in the tables below, the results in some cases represent average values from fewer than three Ekman samples. Identification and counting was made down to major taxonomic level(s). Since chironomids are particularly important indicator organisms, a more detailed analysis of this group was made in representative material from different depths and regions of the lake. Groups that are normally labeled as meiofauna, *i.e.,* ostracods, copepods, cladocerans, and small nematodes, were not included in the study, nor were single individuals of Bryozoa and Hydrozoa that were found.

The bottom material was predominantly sand and clay at most stations. Remains of vegetation were a significant part of the sediment in the shallow areas in both ends of the lake, particularly the northern end, but also at the 15 m depth at stations two and four. The shallow stations in the central part of the lake tended to be sandy.

Results

General character of the fauna. Chironomids and oligochaetes are by far the most common groups in the bottom fauna of Lake Sammamish (Table 2). Molluscs, mainly *Pisidium,* are found at shallow to moderate depths in small numbers. A few crustaceans (*Pontoporeia, Hyalella,* and *Mysis*) occur at 5 and 15 m, and single individuals of Ephemeroptera and Trichoptera are found at the shallow stations. Estimates of the total number of animals per m^2 varies between 7,000 and 28,000, with most stations over 10,000.

The most characteristic of this species is here based on the abundant occurrence of adults of *C. atritibia* around the lake during metamorphosis and emergence of the *C. salinarius* type larvae which dominate the bottom fauna in the profundal. This larval type is also associated with *C. atritibia* in the Okanogan lakes in southern British Columbia (Saether and McLean, 1972). *Phaenopsecrtra* (predominantly *coracina*) is another typical form in the profundal of the lake. The littoral and sublittoral areas are dominated by species of *Cladotanytarsus* and *Tanytarsus.* Altogether 21 chironomid taxa have been found.

Regional and bathymetrical variation. The bottom fauna has a rather even distribution within each region of depth. An exception is the southern end of the lake, which differs both qualitatively and quantitatively. Thus the number of oligochaetes is 4-6 times higher at station nine than at the other shallow stations and 2-3 times higher at station 10 than at other 15 m stations (Table 2). A comparison of the chironomid fauna shows that fewer species are present in the southern end of the lake than in the central areas. A total number of seven chironomid taxa were found at 5 and 15 m depths in the southern, compared to 13 and 12, respectively, at the same depths in the central part of the lake (Table 3). This difference is typical of local enrichment and probably related to the input of allochtonous material through Issaquah and Tibbetts Creeks. (A qualitatively poor fauna is also likely to be found in the northern-

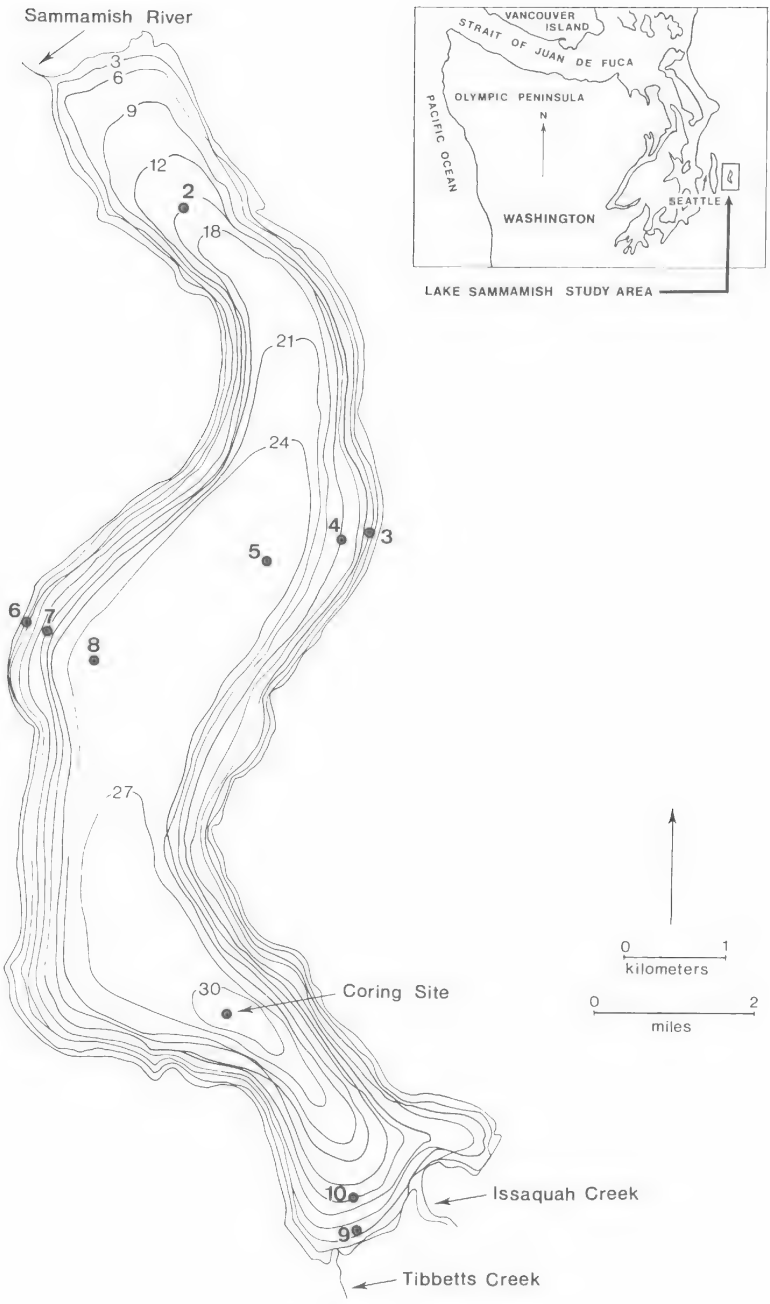

Figure 1. Lake Sammamish with depth contours and sampling stations.

TABLE 2. Average abundance of the bottom fauna in Lake Sammamish.

	5 m						15 m								25 m			
	St. 3		St. 6		St. 2		St. 2		St. 4		St. 7		St. 10		St. 5		St. 8	
	n=2 (x¼)[1]		n=2		n=2		n=2		n=2 (x½)[1]		n=3		n=3		n=4		n=4	
	ind/m²	%	ind/m²	%	ind/m²	%	ind/m²	%	ind/m²	%	ind/m²	%	ind/m²	%	ind/m²	%	ind/m²	%
Chironomidae	6028	80.5	9317	88.4	9157	66.5	1119	15.8	5298	45.1	3106	45.0	2755	18.0	24331	86.4	22173	78.2
Oligochaeta	1187	15.8	746	7.1	4247	30.8	434	6.2	411	3.5	76	1.1	259	1.7	3745	13.3	6178	21.8
Pisidium	183	2.4	381	3.6	343	2.5	5435	77.6	5663	48.2	3654	53.0	12300	80.3	80	0.3		
Gastropoda							15	0.2										
Pontoporeia									365	3.1								
Hyalella			15	0.1														
Mysis					15	0.1					61	0.9						
Ephemeroptera			61	0.6														
Trichoptera	91	1.2	15	0.1	15	0.1												
	7489		10535		13777		7003		11737		6897		15314		28156		28351	

[1] Subsampled

TABLE 3. Chironomid species (larvae) abundance at selected stations in Lake Sammamish. Note the different sample sizes (n).

	5 m		15 m		25 m	
	St. 6 (n=1)	St. 9 (n=1)	St. 7 (n=3)	St. 10 (n=3)	St. 5 (n=4)	St. 8 (n=4)
Tanypodinae						
Procladius	7	13	19	9	1	
Ablabesmyia	2					
Diamesinae						
Monodiamesa			1			
Protanypus			1			
Orthocladiinae						
Parakiefferiella	5					
Heterotrissocladius	1		31	2		
Chironominae:Chironomini						
Chironomous anthracinus type			1			
C. plumosus type[1]		1	2	5		
C. salinarius type			112	95	2086	1930
Cryptochironomus	1					
Cryptocladopelma	8	8				
Cryptotendipes	3	1				
Pagastiella	2		1			
Paracladopelma			11			
Paratendipes	4		1			
Phaenopsectra (2 spp)	2		20	56	44	12
Polypedilum	3					
Chironominae:Tanytarsini						
Cladotanytarsus	38	86				
Micropsectra		1		3		
Tanytarsus	25	7	1	11		
Unidentified	4		3			

[1] including *semi-reductus* type.

most part of the lake, where preliminary sampling revealed an enormous amount of coarse debris in the sediment.)

No evidence of effects from land development west of the lake was found in this survey, but it could show up with more intensive sampling. Increased siltation through water runoff combined with local enrichment would result primarily in higher abundance of oligochaetes in the western compared to the eastern nearshore areas. On the other hand, an increased supply of clay would only depress the number of animals.

As might be expected, the bottom fauna distribution shows a strong variation with depth (Table 2). Chironomids make up 70-90 percent of the fauna at the 5 m depth with 6,000-9,000 ind/m^2. The oligochaete abundance at that depth is 700-1,200 ind/m^2 in the central part of the lake and more than 4,000/m^2 near the inlets. A series of typically littoral-sublittoral chironomid species, predominantly *Cladotanytarus* and *Tanytarus*, characterizes the fauna. In the upper profundal (15 m), oligochaetes dominate with approximately 50 percent of the total number of animals in the main part of the lake and approximately 80 percent in the south and north ends. The abundance values are 1,200 ind/m^2 in the south and 4,000-6,000 in the rest of the lake. Among the chironomids, the most abundant is the *C. salinarius* type, which was not found in the sublittoral. *Phaenopsectra* follows in dominance. In the deep profundal, chi-

ronomids dominate again with 80-90 percent of the total fauna and 22-24,000 ind/m^2. The oligochaetes reach 4,000-6,000 ind/m^2. The *C. salinarius* type is the principal dominating chironomid species. A low but constant number of *Phaenopsectra* are also present in the material along with a single individual of *Procladius,* which brings the total number of chironomid taxa to three.

The abundance values given above are arithmetic means. Standard deviations for chironomid densities are on the average 10 percent at 25 m and 20 percent at 15 m depths. For oligochaetes standard deviation is approximately 20 percent at both depths. At 5 m depth the standard deviation is 80-90 percent of the arithmetic means for both groups.

Paleolimnological data. Subfossil chironomid head capsules were extracted from 47, 49, 51, and 52 cm depths in a sediment core taken at 25 m depth in the central part of the lake (Fig. 1). Previous studies show that the 50 cm level corresponds approximately to the year 1830, with an average sedimentation rate of 3.5 mm per year (Rock, 1974). The remains of chironomid larvae were extracted according to methods somewhat modified from Hofman (1971). A total of 48 head capsules were recovered. The composition of the material is seen from Table 4.

TABLE 4. Composition of subfossil and recent chironomids from the deep profundal of Lake Sammamish.

	% at 4-52 cm sediment level	% in recent samples from the deep profundal
Chironomus	92	99
Phaenopsectra	6	1
Procladius	2	<0.1

Since larval bodies are not preserved in the sediment, the species identity of the *Chironomus* heads cannot be positively established; but there is no indication of any morphological difference in the mouth parts compared to the *Chironomus* found in recent samples. Presumably the *Chironomus* species present *circa* 1830 was the same as the species found in the profundal of the lake today, *i.e., C. atritibia.* Even though the subfossil material is scarce, the composition shows a striking similarity to that of today.

Discussion

Comparison with other lakes in the Lake Washington drainage area. Thut (1965) found that the bottom fauna of Lake Washington was dominated by chironomids down to a depth of 25-30 m. Below that depth the oligochaetes were in the majority. This distribution is normal in most waters. Among the lakes in the Lake Washington drainage area, only Lake Washington and Chester Morse (Bissonnette, 1974) have a higher abundance of oligochaetes than chironomids in the deep profundal. In Lake Sammamish and Findley Lake chironomids are more numerous, with the *C. salinarius* type completely dominating. Both latter lakes provide extreme environmental conditions in the profundal-periodically anoxic conditions and a short growing season, respectively. Apparently the *Chironomus* larvae are better able to exploit these conditions than the oligochaetes. (The numerical relation between the two groups de-

pends upon the methods used. The use of a considerably smaller mesh size in the sieving procedure might alter the balance somewhat.)

Crustaceans are abundant only in Chester Morse. Their absence in Findley is explained by elevation and dispersal barriers, whereas predation probably is a negative factor in Lake Sammamish and Washington. In Lake Sammamish the profundal oxygen conditions are lethal or unfavorable to most amphipods in late summer, which would tend to force the animals toward shallow areas and increased predation pressure.

Although oligochaetes are dominating in the deep profundal of Lake Washington, in contrast to Lake Sammamish, a comparison of existing data indicates that their abundance is generally higher in Lake Sammamish. At 10 m depth, the shallowest station sampled, Thut (1965) found 500-600 ind/m^2 during June-August 1965 compared to 700-1,200 ind/m^2 at 5 m depth in central Lake Sammamish in the present study. Further, values generally under 1,000 were reported for the depth zone 15-30 m in Lake Washington for the same period compared to 3,600-5,700 at 15 m in the central part of Lake Sammamish. From 40 m and down abundance values ranged within 1,100-6,900 in Lake Washington, compared to 3,700-6,200 in the deeper part of Lake Sammamish.

Chironomids are also more abundant in Lake Sammamish. Comparison of data from shallow areas of the two lakes is not very informative, since different depths were sampled and the chironomids are known to show a strong numerical gradient in the nearshore areas. From 15 to 30 m the mean number of chironomids decreased from 3,000 to 1,000 ind/m^2 in Lake Washington, whereas 3,100-5,300 was recorded from 15 m depth in the central part of Lake Sammamish. Values comparable to those mentioned for Lake Washington were found only at the stations in the northern and southern ends of Lake Sammamish. The deep profundal areas exhibit the most striking differences between the two lakes. Thus, mean values for Lake Washington were well under 1,000 chironomids per m^2 below 30 m depth compared to 22,000-24,000 at 25 m depth in Lake Sammamish. These values are among the highest reported in the literature from the profundal of a lake.

Among other animal groups, the molluscs, predominantly *Pisidium*, seem to be slightly more abundant in Lake Sammamish at moderate depths, but more abundant in Lake Washington within the deepest areas.

The quality of the chironomid fauna and its relation to the trophic state of the lakes is discussed in a special paper (Wiederholm, in preparation) and will not be dealt with in this study. Briefly, however, the quality of the chironomid fauna reflects the trophic differences that exist between the various lakes in the Lake Washington drainage area.

A comparison with earlier data reported from Lake Sammamish shows that the values found in the present study are considerably higher. Bissonnette (1974) sampled one station at 25 m depth monthly from April 1973 to March 1974. The number of chironomids varied between 1,200 and 3,800 ind/m^2. Approximately 2,600 ind/m^2 were found in July 1973 and only 2,000 ind/m^2 were present in March 1974 compared to 22-23,000 in July the same year. This 10-fold variation may reflect varying success in emergence and egg-laying between the two years, but it may also reflect a two-year development for part of or for the whole population as shown by Jónasson (1972) for *Chironomus anthracinus*. Also the number of oligochaetes found by Bis-

sonnette (generally below 1,500 ind/m^2) was lower than in the present study. Contrary to the third and fourth larval instars of *Chironomus*, the outcome of oligochaetes may vary with the mesh size used in sieving—0.5 m compared to 0.4 mm in the present study—in addition to possible differences in population density between the 2 years.

Bottom fauna and trophic status. The qualitative composition of the chironomid fauna of Lake Sammamish is clearly indicative of mesotrophic conditions. Both *Phaenopsectra* and *C. atritibia* are leading mesotrophic indicator species (Saether, 1974). Several other species are typically associated with mesotrophic-oligotrophic conditions when occurring in the profundal. Among them are members of *Monodiamesa, Protanypus, Heterotrissocladius,* and *Paracladopelma,* which are represented at 15 m in the central part of Lake Sammamish. Their absence in the deeper areas is probably related to the periodically severe oxygen conditions, caused by the lake morphometry, and the very high abundance of *C. atritibia.*

The significance of the occurrence of *C. atritibia* in Lake Sammamish cannot be overestimated. Traditionally, oxygen has been considered the most important factor in regulating the composition of the profundal benthic communities and the succession of chironomid species between lake types of different trophic states. If this were the case, the chironomid species in Lake Sammamish, where the oxygen level drops to near zero in the late summer, would almost exclusively be larger larvae of *C. plumosus* (together with *Procladius*) which is considered a more tolerant species and usually associated with highly eutrophic condition (Saether, 1974). This is not the case: oxygen cannot be regarded as the only or even the most important factor in regulating the composition of the chironomid fauna. Instead, food supply, and thus ultimately primary production and sedimentation seems to be of prime importance to the bottom fauna. The typically mesotrophic productivity of Lake Sammamish ($\sim$700 mg C/m^2·day during the growth season) is probably the principal limitation to *C. plumosus* asserting a dominant role in the profundal of the lake.

Similarly, the dominance of *C. salinarius* type larvae in the oligotrophic semi-alpine Findley Lake is noteworthy in view of the fact that allochtonous material gives a significant contribution to the total sedimentation of organic material in this lake. This fact further supports the idea of food supply as being more important than oxygen conditions in regulating the structure of profundal benthic communities.

Paleolimnological evidence of earlier trophic conditions. The composition of chironomids found at a sediment level corresponding approximately to the year 1830 shows that the lake has a mesotrophic history going back to the time before the arrival of European man. This agrees with Rock's (1974) conclusion, based on studies of phosphorus and diatom profiles, that no major trophic changes have taken place in the lake during the last 140 years.

Summary and Conclusions

1. The composition of the bottom fauna agrees with the characterization of Lake Sammamish as mesotrophic. Subfossil chironomids support previous evidence that the lake was mesotrophic before the arrival of European man.

2. The abundance of the bottom fauna is generally higher than in the nearby mesotrophic-oligotrophic Lake Washington. *Chironomus atritibia* is quantitatively the

most important benthic species in the lake with a population density in the deep profundal that exceeds most values in the existing literature.

3. The distribution of the bottom fauna is rather even within each region of depth except for the southernmost part of the lake. Allochthonous material from Issaquah and Tibbetts Creek probably accounts for the lower number of species as well as for the higher abundance of oligochaetes found there.

4. The available material gives no evidence that surface water runoff from land development affects the bottom fauna of nearshore areas in the western part of the lake.

5. The combination of anoxic summer hypolimnion and abundant occurrence of nutrient factors are more important than oxygen in regulating the composition of profundal chironomid communities in general.

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An Inventory of Great Blue Heron (Ardea herodias) Nesting Colonies in British Columbia

Abstract

This report is based on 124 reports of 68 different nesting colonies of the Great Blue Heron (*Ardea herodias*) in British Columbia; all but six of the heronries are or were located on or near the Coast. Almost half of the reports (45%) are from 1970-1974. For 32 heronries for which the tree species used were reported, 37.5 percent were in cottonwoods, 20.3 percent in Douglas-fir, 17.2 percent in alders, and 12.5 percent in spruce. No colonies were in trees less than 30 feet (9.1 m) in height. Mean size of the known colonies was about 29 pairs.

Introduction

The Great Blue Heron (*Ardea herodias*) is one of our larger and better-known birds. These herons are generally colonial nesters and in British Columbia all known colonies are in reasonably large trees. (In other areas the species is known to nest on cliffs, shrubs, or even the ground where trees are not available.) In the Vancouver area, these colonies (termed "heronries") are often threatened by clearing of land associated with subdivisions and other developments. I therefore decided to compile all available data on past and present heronries in the Vancouver area, including tree species, height, and size, as well as the reason for abandonment where this was known. A preliminary report of these data was made (Mark, 1974) that stimulated readers to provide additional data from practically all of British Columbia. This paper presents an inventory of all available data on nesting colonies of the Great Blue Heron in British Columbia.

Data were obtained from a number of sources. Most important of these was the British Columbia Nest Records Scheme (BCNRS) currently housed at the British Columbia Provincial Museum in Victoria. This file contains cards with various details on nesting records of many species of birds in the Province, including *Ardea herodias*. If there is a card related to a particular record of a heronry in the BCNRS, it will be cited in this report as the source, regardless of whether or not the record has been published elsewhere. The second most important data source was published accounts, followed by personal communications to me. In the case of duplicate records, published accounts will be given priority. The most limited source of data was my own field work. I did not attempt to visit many of the heronries. Disturbance of colonies should be minimized, and visits to colonies should be made only for research purposes and not simply to satisfy the observer's curiosity. Exact details of the locations of heronries have generally been omitted from the accounts below; readers who desire such information for research purposes should obtain it directly from the sources cited in this paper.

A synthesis of nesting data on any species for an area as large as British Columbia cannot be made without the cooperation of many professional and amateur naturalists

and groups. Observers throughout the Province are encouraged to report details each year for the heronries in their areas to the BCNRS, to me, or preferably, to both.

For purposes of discussion and illustration, British Columbia has been divided into six regions (Fig. 1): A: Queen Charlotte Islands and North Coast; B: North and Central Vancouver Island, Central Coast, and Adjacent Islands; C: Southern Vancouver Island and Gulf Islands; D: Vancouver Area; E: Eastern Fraser Valley; and F: Interior. After the regional accounts, a table will be presented to summarize the data sources and characteristics of the heronries.

A: *Queen Charlotte Islands and North Coast Region.* This entire region is within the breeding range of *Ardea herodias* (Godfrey, 1966), but observers are few, and hence there are only three breeding records available for the region, only one of which contains a definite report of a heronry *per se.*

Brooks and Swarth (1925) reported four colonies from British Columbia; one of these was from Massett (Fig. 1, A1), presumably *circa* 1920. Munro and Cowan (1947) cited evidence that the species bred on Kunghit Island in 1946 (A2), and Brooks (1923) noted that Great Blue Herons are "common and must breed" on Porcher Island (A3). There are no other records, but the species is probably a rather common breeder throughout the region.

B: *Northern and Central Vancouver Island, Central Coast, and Adjacent Islands.* Again the entire area is within the breeding range of the species, and probably because there were more observers, there are seven known colonies in the region.

Richardson (1971) noted that Great Blue Herons are "nesting on many sites in the area" of Grant Bay and Browning Inlet, northwestern Vancouver Island (Fig. 1, B1); the single symbol thus represents more than one colony, but how many more is

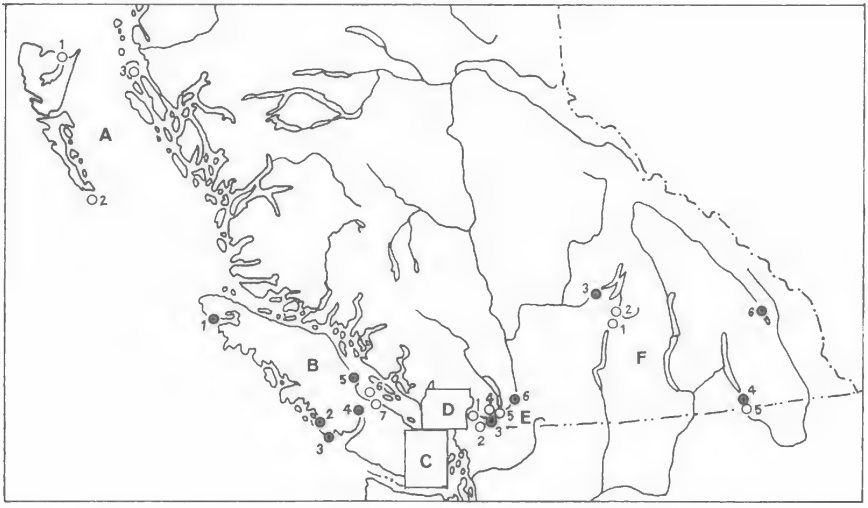

Figure 1. Distribution of Great Blue Heron nesting colonies in British Columbia. Areas C and D are shown in Figures 2 and 3, respectively. Open symbols represent colonies inactive in 1974, or not reported since before 1965; solid symbols indicate colonies active since 1965 and not known to have been abandoned. There are no known heronries in northern British Columbia (not shown).

not known. Hatler *et al.* (1974) reported that while no exact heronry locations are known in Pacific Rim National Park, there are probably at least two colonies in the area (1974)—south of Clayoquot Sound (B2) and east of Ucluelet (B3). There is a BCNRS card for a heronry on the Somas River at Port Alberni (B4). This colony had 10 nests in 1971. Butler (p.c. = personal communication) knew of a recently active (1973) heronry at Bates Beach on the east coast of Vancouver Island (B5). The BCNRS contains five reports of a Great Blue Heron nesting colony on Hornby Island (B6). This heronry was primarily in alders with some nests in maples, and was reported each year from 1959 to 1963. In the latter year there were approximately 30 nests. Finally, Brooks and Swarth (1925) reported a colony near Qualicum (B7) which *circa* 1900 was thought to be the largest in British Columbia; this would probably indicate more than 100 nests.

C: Southern Vancouver Island and Gulf Islands. Since there are very many known heronries from this area the region is shown at a larger scale in Figure 2.

Cowan (p.c.) reported a heronry active in 1939 at Ladysmith (Fig. 2, 1). He also reported the following numbers for a colony on Secretary Island (2): 1932- one nest; 1933- 4; 1934- 12; and 1935- 44 nests. The latter record was cited by Munro and Cowan (1947). A large heronry at Crofton (3) has been noted: 1970- 40 nests (Tatum, 1971); 1971- 48-50 nests (BCNRS); 1973- 51-59 nests (BCNRS). This colony was located in cottonwoods about 60 feet up.

There are five known colonies in the Cowichan Bay area. One at Genoa Bay (4) had 16 nests in 1970, 22 in 1971, and 17 in 1972 (all BCNRS). The colony was reported as in alders in 1970 but in cottonwoods in 1971. Cowan (p.c.) noted a colony at "Cowichan Bay" (5) in 1939; the exact location was not given, and it may in fact coincide with (4) or (7). Another heronry (6) is known from Cowichan Station; there were seven to nine nests there in 1972 (BCNRS). A colony of about 12 pairs was located in alders at Cowichen Bay Village in 1973 (BCNRS), and Cowan (p.c.) reported an active heronry at Cherry Point (8) in 1939.

Campbell (p.c.) reported a colony on Prevost Island (9) consisting of 59 nests in 1974, and Brooks (p.c.) noted a single Great Blue Heron nest on North Pender Island (10) in 1974. Munro and Cowan (1947) cited a heronry of unspecified size on Saturna Island (11) in 1920. Probably the same colony was reported earlier (BCNRS) as being active in 1913 120 feet up in a "fir" tree (probably Douglas-fir). The BCNRS contains a card for a colony near Schwartz Bay (12) in 1970. Drent *et al.* (1964) recorded a colony on Mandarte Island (13) in 1945. This consisted of seven nests in Douglas-fir and arbutus, and was not active either before 1936 or after 1951. Campbell (p.c.) reported a colony of 30 pairs in 1974 on Sidney Island (14).

Tatum (1973) stated that "the localities of the heronries in the south [of the Victoria area] remain inexplicably unknown." Nevertheless, the Thetis Park Nature Sanctuary Association (1974) reported "two or three" heronries in or near that Park; two are shown in that area on Figure 2 (15, 16). Great Blue Herons were nesting 70 feet up in a Douglas-fir on Chatham Island (17) in 1929 (BCNRS). There were also five reports of three different colonies in the Sooke area in the BCNRS. These were: Stoney Creek (18): a new colony of two nests in 1961; Whiffen Spit Road (19): 23 in 1960 ,and 20 pairs in 1961; Otter Point Road (20): eight nests in 1961, and active with no count in 1960.

D: *Vancouver Area.* The Vancouver Checklist area, as defined by Campbell *et al.* (1972a), is shown in Figure 3. A preliminary report on the heronries in this area has been presented elsewhere (Mark, 1974), but more data are now available.

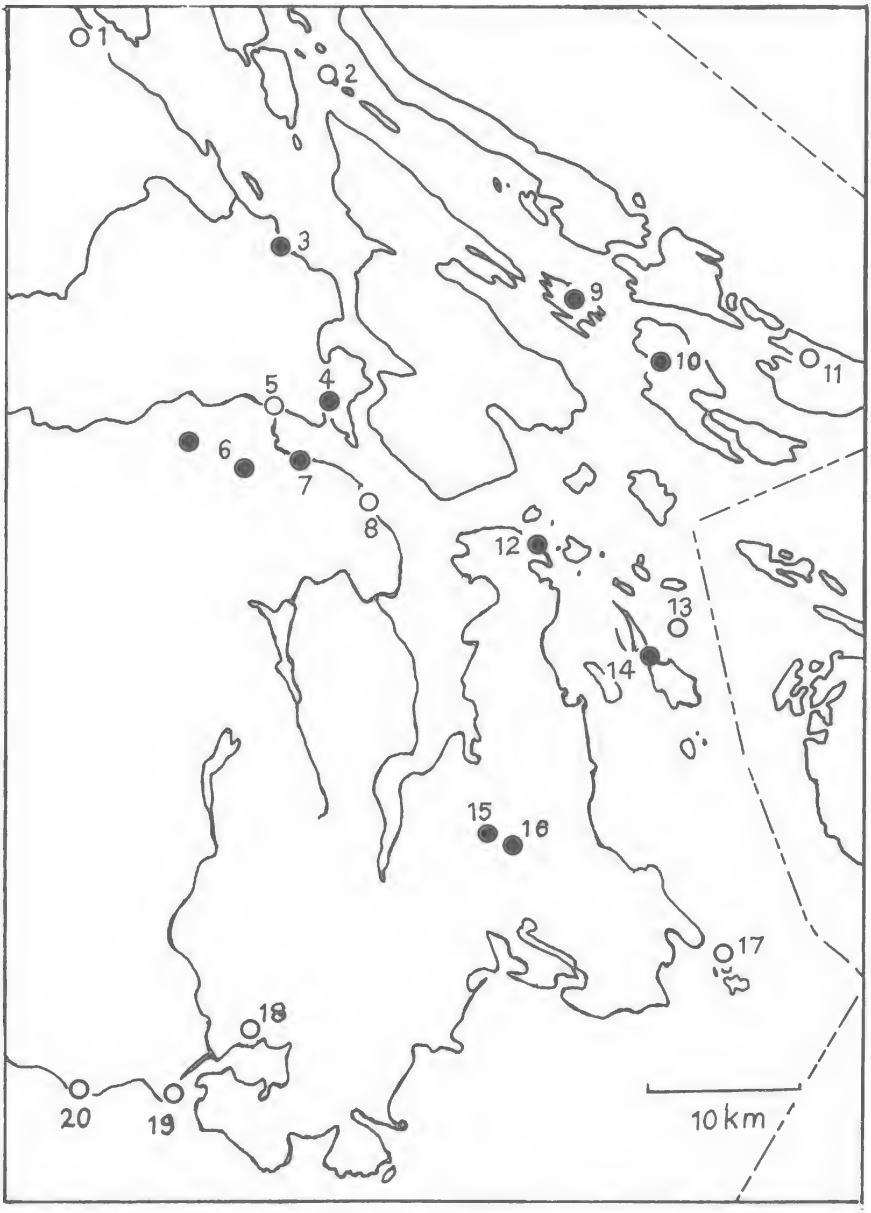

Figure 2. Distribution of heronries in area C: Southern Vancouver Island and Gulf Islands. Symbolism as in Figure 1.

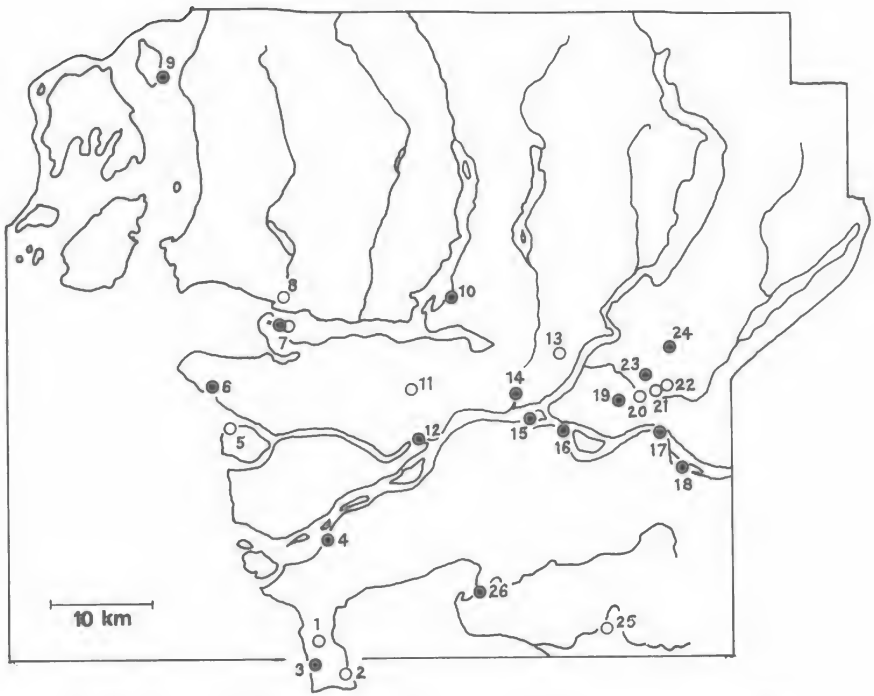

Figure 3. Distribution of heronries in area D: Vancouver area. Symbolism as in Figure 1.

A heronry of 100 nests, possibly the largest in British Columbia at that time, was located off Raitt Road in Delta (Fig. 3, 1) in 1959 (BCNRS). This colony was destroyed by development after that breeding season. Nests were some 60 feet up, apparently in cottonwoods (Mark, 1974). Two other colonies are known from Point Roberts just south of the Canada-U.S.A. border. (These are included here because Point Roberts has in the past been included in the Vancouver Checklist area.) A colony of unknown size was apparently destroyed by development (Mark, 1974) sometime around 1970 (2), and a group of about 30 nests (3) in alders was found in 1973 (Mark, 1974); the colony was active again in 1974. (1), (2), and (3) probably represent three locations of a single colony forced to move twice by clearing of land.

A small colony of three nests 30 feet up in alders was reported on Crescent Island, Delta (4) in 1962 (BCNRS): it was active again in 1963 (BCNRS) but was reported as abandoned in 1967 by Urhahn (1968). A single, recently active nest about 60 feet up in a cottonwood was found after the 1974 season in the same general area. A colony on Sea Island (5) had 40 nests in 1941 (Munro and Cowan, 1947) and was reported as being 90 feet up in alders in 1943 (BCNRS). The colony was still active in 1945 and in 1949 (Cowan, p.c.), but was apparently destroyed by airport expansion. These birds may have moved northward to the U.B.C. Endowment Lands (6), for Krebs (1974) observed that the latter colony is located far north of the center of the birds' present feeding area; the former Sea Island colony is closer to the center of that area.

The U.B.C. colony (6) has declined recently—there were 125-130 nests in 1970 (BCNRS), 78 in 1971 (Krebs, 1974), and only 30 active nests known in 1972 (Krebs, 1974). The 1970 figure is the largest reported size of a Great Blue Heron colony in British Columbia. Birds seen flying near the colony during the 1973 and 1974 breeding seasons strongly suggest that the colony is still active, but the size in these years is unknown. The colony was 60 to 100 feet up in a grove of alders surrounded by mixed forest.

Perhaps the best known Great Blue Heron nesting colony in British Columbia is located in Stanley Park (7). When discovered in 1921 by Racey (1921), there were 39 nests in a single huge spruce at Brockton Point. There were 23 active nests there in 1923 (Munro and Cowan, 1947). The colony was still located in the same area in 1959 (Verrcalt, 1963), with 25+ nests in Douglas-fir in 1961 (BCNRS), 28 in 1966 (BCNRS), and 40 in 1967 (BCNRS). In records listed simply as "Stanley Park," there were 25 nests in 1968 (BCNRS), occurrence with no count in 1969 (BCNRS), and 40 nests in 1970 (Campbell *et al.*, 1972a). In February of 1974, there were some 21 nests in two large Douglas-firs in the zoo area, but the Brockton Point location appeared to have been abandoned for some time (Mark, 1974). The zoo area heronry was active again in 1974 (Mark, 1974). The exact timing of and reasons for the move from Brockton Point to the zoo area remain unknown.

Bent (1926) cited a heronry of 18 nests in 1923 located one-half mile from Burrard Inlet opposite Stanley Park (8), and a colony, probably the same one, was active in North Vancouver in 1929 (BCNRS). There has apparently not been an active heronry in the area in recent years, but the date and reason for the abandonment of the colony remain unknown. Selander (p.c.) has observed a colony on the southeast side of Anvil Island (9) which was active in 1972, 1973, and 1974. Meyer (p.c.) reported another colony north of Sasamat Lake (10) in 1974.

In 1933, a heronry in Burnaby was reported (BCNRS); Cowan (p.c.) stated that this colony was on the north side of Burnaby Lake (11) and was active in 1942. Subsequent status of this heronry is not known, but there is no active heronry there now (1974). Mark (1974) cited reports of a small colony in cottonwoods on Poplar Island (12) which was active in 1973 and had some 10 nests in 1974.

A large colony of 78 nests in Coquitlam (13) was studied in 1971 in some detail (Campbell *et al.*, 1972b, p. 64). This heronry was disturbed by development, although the trees in which the birds were nesting were not felled. The colony was abandoned in 1973, but a statement by Krebs (in Campbell *et al.*, 1974, p. 22) implies that it was still active in 1972. Most of the nests were in spruce trees. Jerema (1973) discovered another Coquitlam-area heronry located on the Essondale Indian Reserve (14). This colony had 48 active nests in 1973 and was active again in 1974 (Mark, 1974). The colony was primarily in spruce, and was apparently established "many years" before 1973 (Jerema, 1973, p. 22).

Four colonies are known from along the Fraser River between New Westminster and the eastern edge of the Vancouver area. Colonies at Douglas Island (15), Tynehead (16), and Edgewater Bar (17) are all in the cottonwoods which line much of the banks of the lower Fraser River. These were all cited by Mark (1974) from communications to him from persons working on the Fraser: (15) and (16) were reported in 1973, (17) in 1974. The fourth heronry is located at Fort Langley (18) and had 10-12 nests in 1963 (BCNRS) and 31-35 in 1964 (BCNRS), 80 feet up in

a spruce. The colony was still active in the early 1970's, but its present status is not known to the writer. A BCNRS report of a colony 85 feet up in a "fir" in 1944 in "Langley" may or may not refer to this colony.

There are six past or present colonies known from the Pitt Meadows-Maple Ridge area. A small colony of perhaps six to eight pairs in Pitt Meadows (19) was reported by Pickens (p.c.) as being a new nesting site in 1974. There is also a BCNRS card for a 1973 heronry of 15 pairs in "Pitt Meadows" (exact location not given) 30-60 feet up in conifers. This may represent colony (19), or another not shown on the map (Fig. 3). The "Dewdney heronry" (20) (Campbell *et al.,* 1974) had about 10 pairs in 1972 (11 pairs according to a BCNRS card), nine pairs in 1973 (BCNRS), and was abandoned in 1974, for reasons unknown (Pickens, p.c.). This colony was in "fir." A somewhat larger colony (21) of 20 pairs in 1963, was located in a single large spruce (BCNRS). It had about 30 pairs in 1970 but was abandoned in 1971, apparently because the tree died. A colony of nine pairs (22) was located just northeast of colony (21) in 1973 (BCNRS), but was abandoned the following year because a Red-tailed Hawk (*Buteo jamaicensis*) had taken over one of the nests (Pickens, p.c.). A new colony in 1974 (Pickens, p.c.) was established on the North Alouette River (23) and had 10 nests, while another new 1974 colony (24) of the same size was established in the U.B.C. Research Forest (Pickens, p.c.).

In the south Surrey-Whiterock area, two heronries have been reported. One on the lower Campbell River (25) remains unconfirmed (Mark, 1974), and Urhahn (1968) indicated a colony on the lower Nicomekl River which was said to be active in 1967. No size was indicated, and its subsequent status is unknown.

E: *Eastern Fraser Valley.* There are fewer reports of colonies from this region, although the species probably occurs throughout this area as it does farther west. In an article in *The Columbian* newspaper 24 April, 1971, Dr. Rudi Drent was quoted as saying that "there are currently about 1200 pairs of blue herons in the lower Fraser Valley." The known colonies account for less than half of this number.

A long-established *Ardea herodias* colony has been reported from the mouth of the Stave River at Ruskin (Fig. 1, E1). A colony was reported from this area *circa* 1900 by Brooks and Swarth (1925). A heronry of 20-30 pairs in 1963 and 35 pairs in 1964 was reported from 50 feet up in cottonwoods on Crescent Island opposite Ruskin (BCNRS). The subsequent status is unknown. Chapman (1890) reported a colony "10 miles from Mt. Lehman" in 1888; this represents the earliest report of the nesting of this species in British Columbia known to me. The exact location is unknown, so it is plotted at Mt. Lehman on the map (E2). Sargent (p.c.) has observed a colony near the mouth of the Chilliwack River (E3) which had 27 nests in 1974. This heronry was 40 to 60 feet up in cottonwoods. An earlier colony in the Chilliwack area (E5), also in cottonwoods, was reported in Bent (1926). Although use of deciduous trees was at that time considered to be unusual, it certainly is not so now. Another colony active from 1957 to 1960 was reported (BCNRS) from the mouth of the Chehalis River, Harrison Bay (E4). Butler (p.c.) notes a colony near Hope in 1974 (E6).

F: *Interior.* The breeding range of the Great Blue Heron in the Interior of British Columbia is probably restricted to certain valleys in the more southerly part. Where-

as the species has been reported in summer from most of the Interior, those in the central and northern areas probably represent non-breeders or the post-breeding dispersal common in the Heron family.

The BCNRS contains cards for a colony at Otter Lake, south of Armstrong (Fig. 1, F1) in 1962 (12 pairs) and 1963 (24 pairs). The colony was 35-40 feet up in aspens. Munro and Cowan (1947) reported a small colony of two+ pairs in Douglas-fir in 1945 and 1946 at Gardom Lake near Enderby (F2). There is also a BCNRS card for a heronry of unspecified size 35 feet up in "fir" at Chum Lake, Squilax (F3) in 1973.

The breeding of the species in the Creston area has long been established. Munro (1950) reported a total of about 40 pairs in the area in 1947-48, of which 20 pairs were in one colony in cottonwoods (F4); other smaller heronries and single nests, mostly in aspen, made up the remaining 20 pairs (F5). Westendorp (p.c.) reports that there is presently only one large colony in the area, with about 60 pairs in 1968, 90 in 1971, and 110 pairs in 1973.

The only other colony known to me from the Interior was reported in an editorial in *B.C. Outdoors* (August 1973). The heronry was located in old cottonwoods "over 200 feet tall" between Columbia and Windermere Lakes (F6). There were about 10 pairs in 1973 and some 25+ pairs around 1963.

Summary

There are 124 reports of a total of 68 heronries, past and present, in British Columbia. This figure very probably represents a small proportion of the heronries in the Province: the species is a common breeder throughout the Coast, and only three reports are available from north of Vancouver Island. The distribution of various characteristics of the known heronries among the regions of the Province are summarized in Table 1.

TABLE 1. Summary of data on Great Blue Heron nesting colonies in British Columbia.

Region:	A	B	C	D	E	F	Total
Characteristics of the Data:							
Number of Records (Total)	3	11	30	57	11	12	124
Sources of Data: BCNRS	–	6	15	19	6	3	49
Published Accounts	3	4	6	25	3	6	47
Other	–	1	9	13	2	3	28
Year of Reports:							
Pre-1920	1	1	1	–	2	–	5
1920-1939	1	–	9	5	1	–	16
1940-1959	1	1	1	8	3	4	18
1960-1969	–	4	5	12	3	5	29
1970-1974	–	5	14	32	2	3	56
Characteristics of the Heronries:							
Number of Heronries	3	7	20	26	6	6	68
Mean Size:							
100+ pairs	–	1	–	1	–	–	2
80-99	–	–	–	–	–	–	–
60-79	–	–	–	2	–	1	3
40-59	–	–	2	2	–	–	4
20-39	–	1	2	4	2	–	9
10-19	–	1	3	5	–	2	11
5-9	–	–	3	2	–	1	6
1-4	–	–	2	1	–	1	4
Unspecified	3	4	8	9	4	1	29

Tree Species:							
Douglas-fir + "fir"	–	–	2½*	2	–	2	6½
Spruce	–	–	–	4	–	–	4
"Conifers"	–	–	–	1	–	–	1
Total Conifers	–	–	2½	7	–	2	11½
Cottonwood	–	–	1½	5½	3	2	12
Alder	–	½	1½	3½	–	–	5½
Aspen	–	–	–	–	–	2	2
Maple	–	½	–	–	–	–	½
Arbutus	–	–	½	–	–	–	½
Total Deciduous	–	1	3½	9	3	4	20½
Unspecified	3	6	14	10	3	–	36
Nest Height (Feet):							
100+	–	–	1	1	–	1	3
80-99	–	–	–	4	–	–	4
50-79	–	–	2	1	2	–	5
30-49	–	–	–	1	–	2	3
0-29	–	–	–	–	–	–	–
Unspecified	3	7	17	19	4	3	53

* For colonies in more than one tree species, each species was recorded "½", since generally the true relative frequencies are unknown.

Great Blue Herons in British Columbia have chosen a wide variety of tree species and heights as nesting sites. Apparently, when a heronry is abandoned, the birds are generally able to relocate easily, provided that large trees of almost any species remain in the area. Nevertheless, naturalists' groups should be aware of heronries in their areas and the need to make every effort to preserve these heronries from disturbance.

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Vegetation of the Abbott Creek Research Natural Area, Oregon

Abstract

This study identifies the different forest communities present in Abbott Creek Natural Area, Oregon. It also describes the floristic composition of each community type and comments on the relative relationships of the communities. The five forest community types described are: *Abies magnifica-Abies concolor/Ribes* spp., *Abies concolor-Tsuga heterophylla/Acer circinatum-Taxus brevifolia, Abies concolor/Linnaea borealis, Abies concolor-Pseudotsuga menziesii/Whipplea modesta* and *Pseudotsuga menziesii-Libocedrus decurrens/Arctostaphylos nevadensis.* To accomplish the above objectives 124 reconnaissance and eleven analytical sample plots were taken. These data were analyzed using SIMORD, a two dimensional ordination procedure.

Introduction

This paper gives the results of vegetation classification studies in the Abbott Creek Natural Area located about 29 km (18 mi) west of Crater Lake in southwestern Oregon. Interest in this area stems from a report by H. J. Andrews (1946) who noticed that: "special features of this area . . . are the volume and stands of sugar pine (*Pinus lambertiana*) . . . As characteristic of these stands, this volume is mainly in the large diameter classes, 50 to 60 inches and over, thus presenting a truly optimum stand of Southern Oregon sugar pine." Andrews also stated that reproduction and advanced growth of the sugar pine was of general occurrence in the natural area. When we revisited here some 25 years after Andrews' report, we were impressed by the complexity of forest communities and by the heavy reproduction of white fir (*Abies concolor*) which on most sites appeared to be the climax tree.

The forest communities of the upper drainage basin of the East Fork of Abbott Creek are quite different from those described from other regions of the Western Cascade Province (Franklin and Dyrness, 1969). The forest types in the Abbott Creek area, however, are within the *Abies concolor* and *Abies magnifica shastensis* zones. The only vegetation studies in these zones are those of Whittaker (1960) and Waring (1969) in the Siskiyou Mountains where the community types are quite different. Therefore, the description of habitats, plant communities, and tree successional relationships at Abbott Creek Natural Area contributes to our knowledge of the natural vegetation of the Cascade Range.

We also began these studies for purposes of stratifying the vegetation of this research natural area and initiating a measurement system and baseline documentation within each community type for future comparisons and additional scientific research (Moir, 1972).

Study Area

Abbott Creek Natural Area is located 19 km (12 mi) west of Crater Lake National Park, in the Rogue River National Forest of southern Oregon (Fig. 1). Its boundaries enclose parts of Douglas and Jackson counties, and the total area is 1076 hectares (2660 a).

The western border of the natural area is defined by the main branch of Abbott Creek and is the location of easiest access to major portions of the area. An unmaintained logging road parallels the more southerly half. This road is easily accessible from U.S. Highway 26 via forest road 3047. The northern border is defined by a ridge which divides the Rogue and Umpqua River drainages. The main access to this border is via Abbott Butte fire lookout, which is serviced by forest road 2923, and the remnants of a trail which follows this ridge. The eastern edge of the area follows the Golden Stairs Trail, for the most part, which is accessible at its southern end by forest road 3017, and by forest road 3016 at a more northerly point. The southern border is short, and is accessible from forest road 3047. There are no trails or roads within the area, the major topographic features of which are shown in Figure 2.

Physiography and Geology

Three drainages make up the major portion of the area, with the northernmost containing almost half of the total acreage. The general topography is quite rugged, with much of the area consisting of slopes of 25 percent or more. There are some portions of gentle to almost no relief along the western edge of the area near Abbott Creek, and some benches at high elevations below Abbott Butte. Many of the ridges between and along the borders of drainages contain rock outcroppings with little vegetation.

The highest point in the area is Abbott Butte, elevation 1869 m (6131 ft), lo-

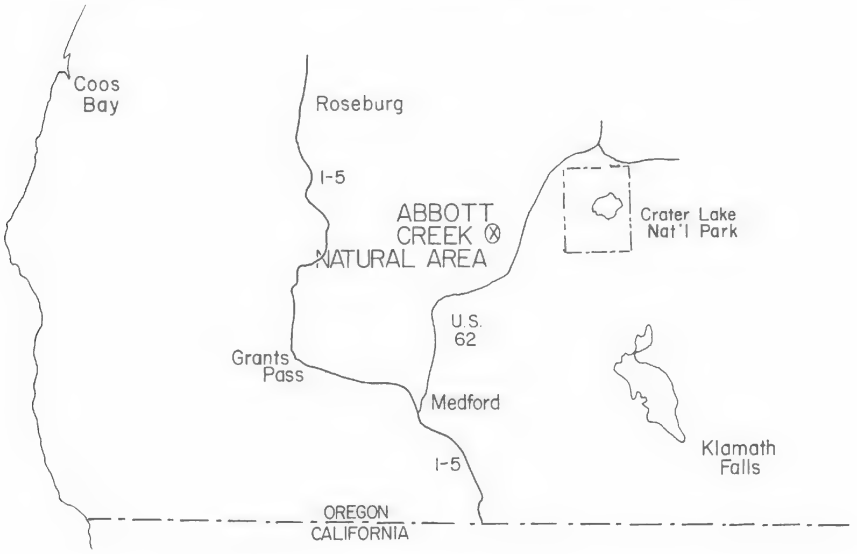

Figure 1. Location of Abbott Creek Natural Area.

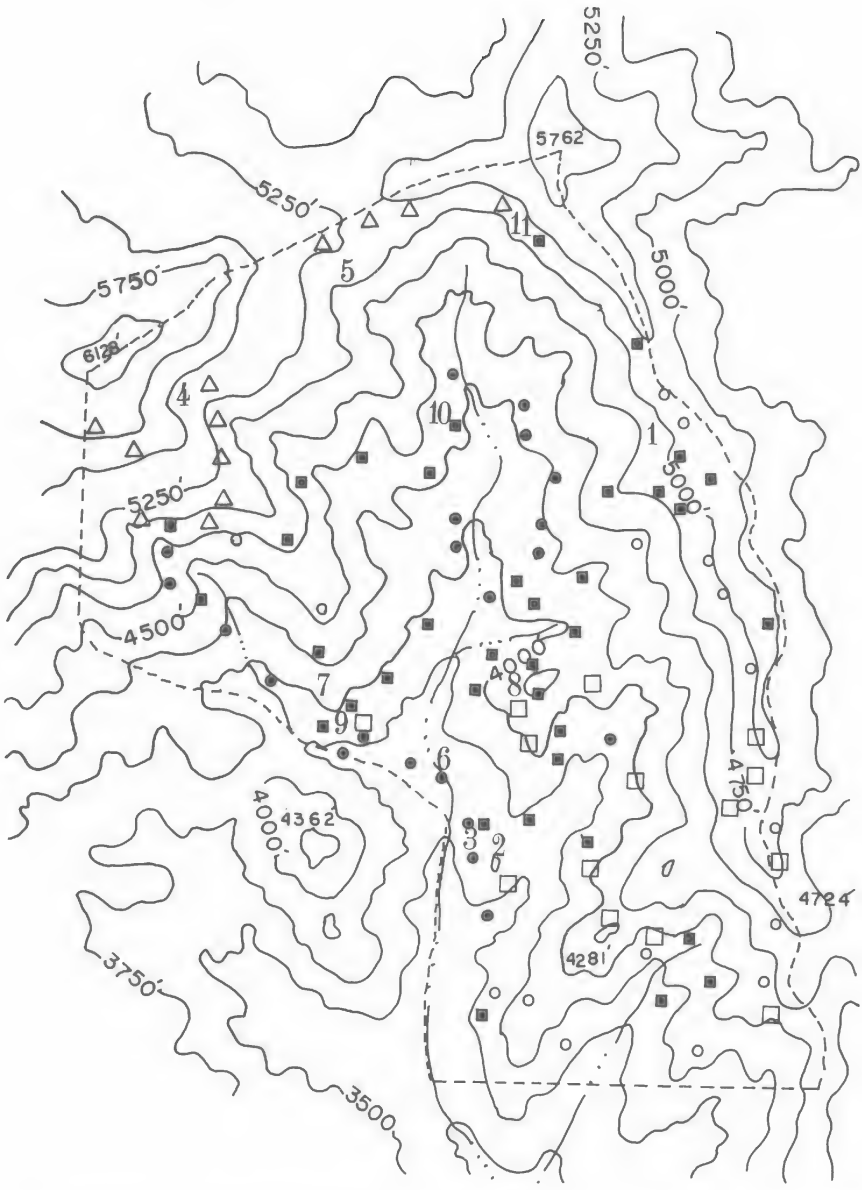

Figure 2. Map of study area showing location of plots comprising the five plant associations designated △ *Abies magnifica* complex. ● *Abies concolor-Tsuga heterophylla/Acer circinatum-Taxus brevifolia* Asso. ■ *Abies concolor-Linnaea borealis* Asso. ○ *Abies concolor-Pseudotsuga menziesii/Whipplea modesta* Asso. □ *Pseudotsuga menziesii-Libocedrus decurrens/Arctostaphylos nevadensis* Asso.

cated in the northwestern corner. The crest of the ridge that parallels the northern border and much of the crest of the ridge paralleling the eastern border are above 1524 m (5000 ft). The southwestern corner is the lowest point, at about 1006 m (3300 ft).

Geologically, the entire area is volcanic in origin. The soil of the natural area is described as belonging to the Freezener-Coyata soil series (Power and Simonson, 1969). Typically these soils are deep and well drained with dark reddish-brown, friable, loam surface layers and clay loam, moderately blocky subsoils. Rock fragments range in abundance from 0 to 30 percent or more by volume. The soils are moderately acid in reaction.

Climate

The climate in the natural area is characterized as "modified maritime." Most of the precipitation is a result of low pressure systems which move eastward across western Oregon from the Pacific Ocean. During the summer, this dominant climatic feature is modified by high pressure systems which shift fronts northward, resulting in clear, dry weather. This phenomenon results in cool, wet winters and warm, dry summers.

Methods

During the summer of 1971 the forest vegetation was sampled by reconnaissance plots (Franklin, Dyrness, and Moir, 1970) and five forest classification units were distinguished (Mitchell, 1972). In the summer of 1972 permanent additional plots were established within each of these types. These plots were 25 x 15 m. All trees within the plots were tallied by species and size class. Understory vegetation was measured by canopy coverage class in each of fifty 2 x 5 dm quadrats systematically placed along two 25 m strips within the plot (Daubenmire, 1968, p. 42 ff, and figs. 13 & 26). All vascular plants in each of the quadrats were measured either in early (June-July) or late (August) summer to insure that each species was observed near its time of maximum foliage. Species not in the quadrats but occurring inside the 25 x 15 m plot were recorded for constance; species of the homogeneous vegetation just outside the plot were recorded for presence.

The plant names (Peck, 1961) of this study are based upon voucher specimens deposited in herbaria at Oregon State University and the U.S. Forest Service at Fort Collins, Colorado.

Permanently marked camera locations were established at each of the 25 x 15 m plots. Here photographs were taken of the existing vegetation within (and sometimes in the vicinity of) the plots.

Data from both reconnaissance and permanent plot samples were analyzed by similarity and ordination procedures, using SIMORD, a reference stand ordination technique (Dick-Peddie and Moir, 1970). We selected reference plots used to define the X and Y axes of the ordination from among the reconnaissance plots that represented, in our judgment, typical and distinctive environments. After several trials of reference plot selection, the resultant ordination distributed the plots in what we considered to be a realistic pattern (Mitchell, 1972, and discussion below). The groupings of the plots on the ordination plane together with synecological and physical site data (*e.g.,* slope, exposure, elevation, landform) not used in ordination were all criteria

aiding us in the definition of the major forest types (Franklin, Dyrness, and Moir, 1970; Daubenmire, 1968).

The vegetation of several herbaceous communities along the Golden Stairs Trail was sampled by systematic location of 25 2 x 5 dm quadrats along a line within each homogeneous vegetation type. The vascular plants in each quadrat were estimated by canopy coverage class in the manner similar to the understory vegetation of the forest plots. The 25 m line in each community is permanently marked by stakes at each end. The measurements were taken the third week of June, 1972.

Results

From the analysis of the original reconnaissance data, five forest community types were designated (Table 1) and named according to their major overstory and understory indicators.

When both the reconnaissance and analytical plots (Fig. 2) were subjected to the SIMORD program the two dimensional ordination pattern depicted in Figure 3 resulted. It can be seen that the plots designated as belonging to the same community type tended to group with each other and that the analytical plots chosen to represent each group fell well within the borders of their specific groups.

One factor of great importance to the designation of overstory indicators was their position in the successional sequence of a given community type. To evaluate this factor, the age structure of these overstory species was determined in each plot (Fig. 4). Of the major overstory species evaluated, *Pseudotsuga menziesii* was unique in that a

TABLE 1. Some major characteristics of the forest communities at Abbott Creek. The asterisk indicates distinguishing features.

CLASSIFICATION TYPE	TREE SPECIES		UNDERSTORY VEGETATION		
	Climax	Late Seral	Total Cover (PERCENT)	Evergreen (PERCENT)	Major Species
Abies magnifica Complex	Abma* (Tsme)	Abco	90-100+	3-10*	*Ribes binominatum* *Achlys triphylla* *Rubus parviflora* *Bromus vulgaris*
Abies concolor-Tsuga heterophylla/Acer circinatum-Taxus brevifolia Association	Abco Tshe	Psme	90-100+	15-70	*Acer circinatum** *Taxus brevifolia** *Vaccinium membran* *Linnaea borealis*
Rhododendron Phase	Abco Tshe	Psme	90-100+	50+	*Rhododendron macrocarpum**
Abies concolor/Linnaea borealis Association	Abco (Tshe)	Psme Lide	60-90*	60*	*Linnaea borealis** *Castanopsis chrysophylla* (shrub)
Whipplea modesta Phase	Abco Lide	Psme	20-75		*Whipplea modesta* *Linnaea borealis*
Abies concolor-Pseudotsuga/Whipplea modesta Association	Abco Lide	Psme	0-20*	0-30	*Whipplea modesta* *Iris chrysophylla*
Pseudotsuga-Libocedrus/Arctostaphylos nevadensis Association	Psme* Lide	Pila	10-40	40-60	*Arctostaphylos nevadensis** *Ceanothus prostatus*
Castanopsis chrysophylla Phase	Psme* Abco*	Lide Pila	30-50	60	*Castanopsis chrysophylla* (tree) *Arctostaphylos nevadensis*

majority of the stands contained old dominant individuals, but no younger individuals. In essence, *Pseudotsuga menziesii* is not reproducing itself in older stands (probably due to its relatively low shade tolerance) and represents a late seral stage species. *Abies concolor* and to a lesser extent *Libocedrus decurrens,* by contrast, were repre-

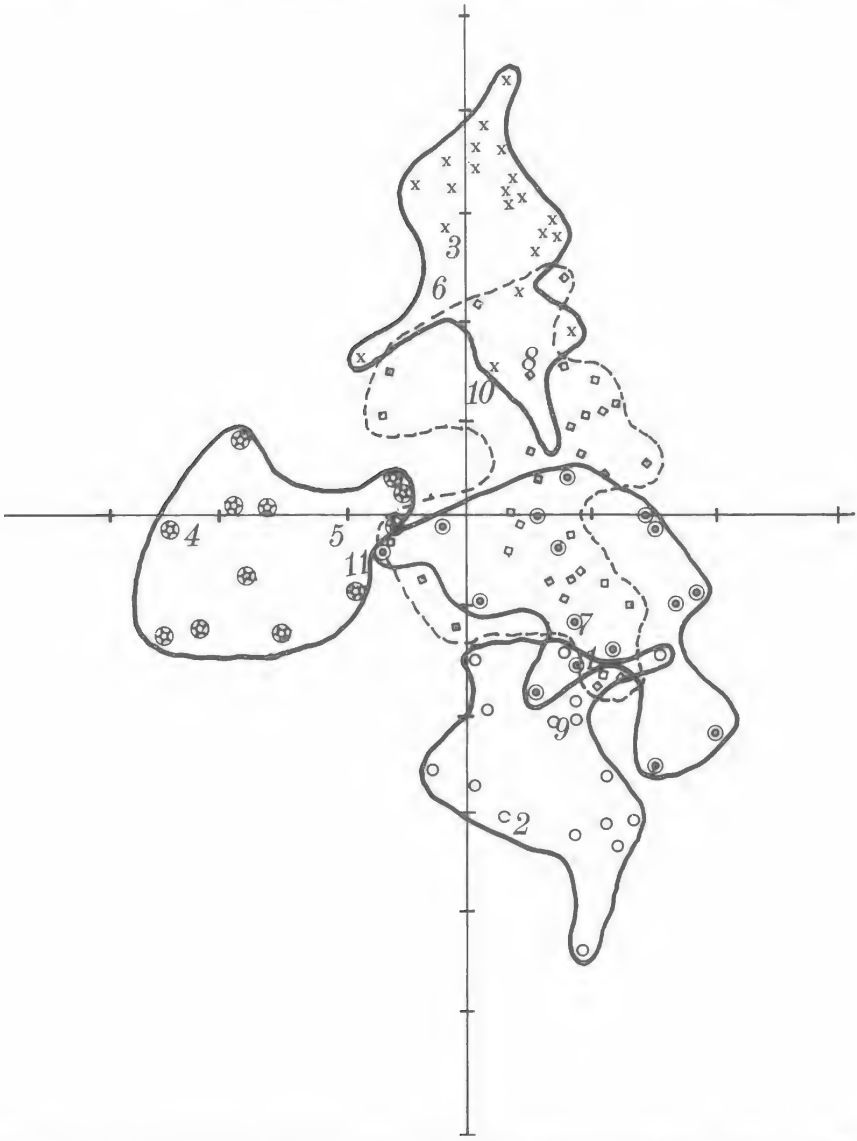

Figure 3. Two dimensional ordination of forest plots of the Abbott Creek Natural Area. *Abies magnifica* complex. X *Abies concolor-Tsuga heterophylla/Acer circinatum-Taxus brevifolia* Asso. □ *Abies concolor-Linnaea borealis* Asso. ⊙ *Abies concolor-Pseudotsuga menziesii/Whipplea modesta* Asso. ○ *Pseudotsuga menziesii-Libocedrus decurrens/Arctostaphylos nevadensis* Asso.

sented by all age classes in the stands in which they occur, and might be considered dominant climax species. However, a climax situation in an area such as Abbott Creek may not be a real situation. Due to the periodic fires which occur, and the opening of the forest by fallen trees, *Pseudotsuga menziesii* may be able to compete successfully and remain the permanent dominant overstory species.

The Vegetation Types

1. The *Abies magnifica* complex is the most extensive in the northwest corner of the natural area below Abbott Butte and Elephant Head. A variety of contrasting high-elevation forest and open meadow communities occur here and in the vicinity of Falcon Butte. The present forests invariably feature *Abies magnifica* in reproductive strata of the understory. The associated climax tree species vary according to local habitat differences. In plots 4 and 5 *Abies concolor* has strong reproduction, and is either a late seral species or shares climax status with *Abies magnifica.* Large specimens of *Libocedrus decurrens,* as well as its prominence as an early meadow invader, indicate the seral nature of this species. Plots 4 and 5 occur on southeast facing exposures of moderate and steep slopes respectively. Plot 11 on steep southwest facing slopes also has abundant reproduction of *Abies concolor* in both young and advanced size classes (Fig. 5). On cool, wet sites sheltered by the cliffs of Elephant Head, *Tsuga mertensiana* exhibits abundant young and advanced regeneration, with *Abies concolor* absent or accidental. Elsewhere almost level benches feature very large *Abies magnifica* and rich herb and shrub understories.

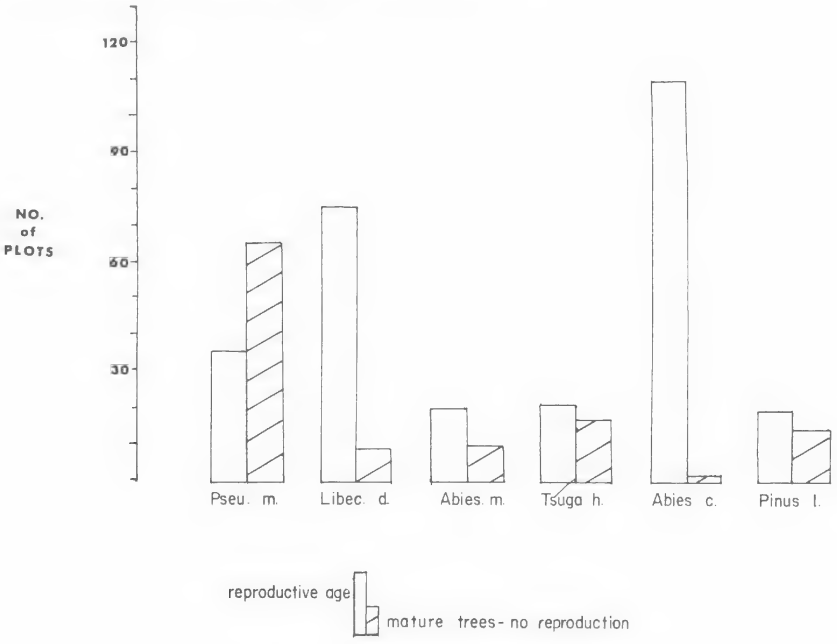

Figure 4. Reproductive and mature age classes of selected tree species.

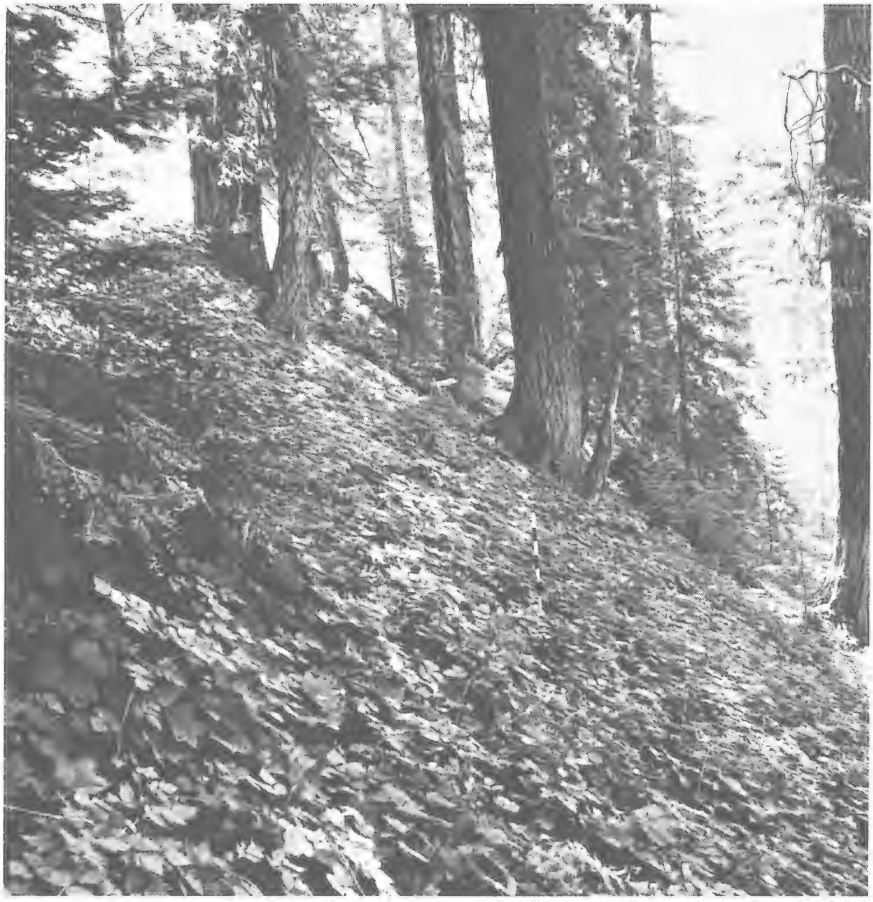

Figure 5. Rich understory vegetation dominated by *Rubus parviflorum* and *Rubus ursinus* in plot 11 of the high elevation *Abies magnifica-Abies concolor/Ribes* spp. complex.

The *Abies magnifica* complex is floristically quite distinct from remaining forest types of Abbott Creek drainage (Table 2). Species such as *Ribes binominatum, Rubus lasiococcus, Erigeron aliceae, Rubus parviflorus, Galium oreganum,* and *Actaea rubra* are generally limited to this high elevation complex; those such as *Adenocaulon bicolor, Osmorhiza chilenses, Montia siberica, Circaea alpina, Vancouveria hexandra, Ribes viscosissimum,* and *Bromus vulgaris* may achieve their greatest cover or density.

In each of the plots of Figure 4 within this complex the total coverage of understory herbs and shrubs is very high, averaging well over 80 percent. *Ribes binominatum, Vicia americana, Smilacina sessilifolia, Galium oreganum,* and *Bromus vulgaris* all have over 8 percent canopy coverage in plot 4. *Adenocaulon bicolor, Achlys triphylla,* and *Vancouveria hexandra* in plot 5 and *Rubus parviflorus, Rubus ursinus, Achlys,* and *Vancouveria* in plot 11 also each have cover values between 7-30 percent. It is noteworthy that the numerous understory species in these plots are mostly decidu-

TABLE 2. List of understory species from permanent plots by percent cover. + Indicate presence of species in the plot at less than one percent cover.

	Abies magnifica Complex			*Abies concolor Tsuga heterophylla/Acer circinatum Taxus brevifolia*		*concolor/ Linnaea borealis*		*Abies concolor Pseudotsuga/ menziesii/ Whipplea modesta*		*Pseudotsuga menziesii Libocedrus decurrens/ Arctostaphylos nevadensis*	
Plot Numbers	4	5	11	3	6	8	10	1	7	2	9
Shrubs-Deciduous											
Ribes viscosissimum	3										
Ribes binominatum	16	4	1								
Rosa gymnocarpa	+	2		1	1		+	+	+	+	
Corylus cornuta		3	+		+	+	2		+		
Acer circinatum				14	74						
Vaccinium membranaceum				7	+	6	+				
Symphoricarpos mollis				2	1			+		+	
Shrubs-Evergreen											
Taxus brevifolia				40	4		2				
Berberis nervosa		3		8	+	6		+	2	+	
Pachystima myrsinites				2	2	1	+		+		+
Castanopsis chrysophylla				+	+	8	+		+	1	+
Gaultheria ovatifolia				+		3					
Rubus nivalis							10				
Arctostaphylos nevadensis										15	13
Ceanothus prostratus										10	+
Garrya fremontii								+		2	
Suffrutescent-Deciduous											
Rubus ursinus		4	30	3	3	1	8	+	+		
Suffrutescent-Evergreen											
Linnaea borealis				5	8	12	25				
Chimaphila umbellata	1	+	3	1	2	5	13		1	1	+
Pyrola secunda						+	1				
Forbs											
Rubus parviflorus	+	+	27	+							
Asarum caudatum	2		7				1				
Adenocaulon bicolor	1	17	4		+			1	+		
Montia sibiricia	1	3									
Smilacina sessilifolia	12	1	3	1							
Osmorhiza chilensis	3	4	1		+				+		
Circaea alpina	4	6	2		+				+	+	
Vicia americana	23	5	6	+	+	+		+		1	
Erigeron aliceae	3										
Galium oreganum	9										
Galium trifolium	2	1	2		+		+				
Vancouveria hexandra	1	7	7	1	+		1				
Pteridium aquilinum	7			+			1				
Arenaria macrophylla	3	2	1			+		1	+	1	+
Hieracium albiflorum	2	2	+	+		+	+	+	+	+	+
Trientalis latifolia	+	5	+	+	+	1	2	+	+	1	+
Trillium ovatum	+	1	+	+	+	1	+				
Anemone deltodia		2	1	1	1	+	+				
Dryopteris				2							
Disporum hookeri		+	+	+	+	1	+	+	+		+
Iris chrysophylla		1		+	+		+	+	1		
Clintonia uniflora				+		1	1				
Campanula prenanthoides		+						1			
Syntheris reinformis					1					+	
Whipplea modesta				2	+	4	9	1	6	8	+

ous, and that the evergreen life form is very poorly represented. This suggests that low winter temperatures are more critical than seasonal summer drought in the survival of understory species (*e.g.,* Mooney and Dunn, 1970; Mooney, 1969).

2. Plots 3 and 6 belong to the *Abies concolor-Tsuga heterophylla/Acer circinatum-Taxus brevifolia* association. Stands of this association are almost exclusively located in or near the bottom of major drainages, usually those with permanent streams. The overstory generally contains large *Pseudotsuga menziesii, Pinus lambertiana,* and, less often, *P. monticola.* The presence of all reproductive size classes of *Abies concolor* indicates this to be a climax tree. *Tsuga heterophylla* is the second climax species; its reproductive abundance is especially evident in plot 3, but scattered individuals of young or advanced regeneration are evident nearly throughout this valley bottom habitat.

The tall shrub layer is extensive and well developed. Both *Acer circinatum* and *Taxus brevifolia* may dominate, either singly or in combination (Fig. 6). Other tall shrubs (or low trees) of this understory stratum are *Corylus cornuta, Cornus nuttallii,* and *Castanopsis chrysophylla.* Lower understory strata may have *Vaccinium membranaceum, Pachistima myrsinites, Linnaea borealis, Achlys triphylla,* and *Berberis nervosa* as major species. Evergreens comprise 16-69 percent of the understory (depending mostly on relative proportions of *Acer* and *Taxus*), with nine evergreen species occurring in the two plots.

3. The *Abies concolor/Linnaea borealis* association is represented by plots 8 and 10. These plots occur on mesic lower slopes of northerly or easterly exposure, adjacent to the drainages supporting vegetation of the above association. Stands of the *Abies concolor/Linnaea borealis* association are found on mesic slopes and draws and are very common in the East Fork Abbott Creek drainages. *Abies concolor* is the sole climax tree on most sites (Fig. 7), although occasional *Tsuga heterophylla* are present in draws and *Abies magnifica* is an accidental. *Pseudotsuga menziesii* and *Libocedrus decurrens* contribute to the reproduction in minor quantities on drier or more open forest conditions. The total understory cover of plots 8 and 10 is quite high (59 and 86% respectively) and rich in evergreen constituents. Major species are shrubby *Castanopsis chrysophylla,* and low shrubby or suffrutescent evergreens including *Linnaea borealis, Chimaphila umbellata, Pachistima, myrsinites, Rubus nivalis, Gaultheria ovatifolia,* and *Viola sempervirens.* The well-expressed understory vegetation is a feature of this community; it contrasts with the drier *Abies concolor-Pseudotsuga menziesii/Whipplea modesta* community discussed below. However, a tall shrub stratum of *Acer circinatum, Taxus brevifolia, Cornus nuttallii,* and others is not nearly as continuous and conspicuous as in the *Abies concolor-Tsuga heterophylla/Acer-Taxus* comunity. Nevertheless, several important species are shared between these two community types, including *Vaccinium membranaceum, Linnaea borealis,* and *Tsuga heterophylla.* The *Abies concolor/Linnaea borealis* association also has some floristic similarity to the high-elevation *Abies magnifica* complex, including high canopy coverage of *Achlys triphylla/Trientalis latifolia,* an infrequent *Abies magnifica* in the forest reproduction, and the presence of such species as *Asarum caudatum* and *Pedicularis racemosa* in both types.

On slightly drier sites such as upper draws or easterly or northerly midslopes, the understory vegetation decreases. *Linnaea borealis* or other evergreen species may be subdominant, minor, or absent. Total ground cover may decline to as low as about

Figure 6. View into plot 6 showing typical *Acer circinatum* dominated tall shrub layer of the *Abies concolor-Tsuga heterophylla/Acer circinatum-Taxus brevifolia* community type.

20 percent. *Abies concolor* continues to be the sole climax tree, for *Tsuga heterophylla* is absent and *Pseudotsuga menziesii* is uncommon in the competing reproduction of *Abies.* We recognize this variation of the *Abies concolor/Linnaea borealis* association as the *Whipplea modesta* phase, for this species often becomes one of the major dominants of the reduced understory flora.

The contribution of evergreen species (about 60% of the understory cover in plots 8 and 10) in many sites of the *Abies concolor/Linnaea borealis* association suggests a higher evergreen understory component than is found on sites of the *Abies magnifica* complex (Mooney and Dunn, 1970; Mooney, 1969).

4. The *Abies concolor-Pseudotsuga menziesii/Whipplea modesta* association is characterized by the presence, often in appreciable numbers, of *Pseudotsuga menziesii* and *Libocedrus decurrens* as persistent late seral or co-climax species. Plots 1 and 7 exhibit all sizes of *Pseudotsuga menziesii* in reproduction (Fig. 8). Another distinc-

Figure 7. All sizes of *Abies concolor* are found in plot 10 of the *Abies concolor/Linnaea borealis* community type. Ground vegetation here consists of *Linnaea borealis, Chimaphila umbellata, Rubus nivalis, Rubus ursinus,* and *Whipplea modesta.* Note lack of any well-developed tall shrub layer.

tion of this community type is the sparseness of the understory (4 and 11% total cover in respective plots 1 and 7). Shrubs (*Castanopsis chrysophylla, Amelanchier florida, Garrya fremontii,* and others) are only occasional or infrequent; the herb layer, mostly dominated by *Whipplea modesta* or *Iris chrysophylla* in patches, is sporadic and weakly expressed by low density populations. *Linnaea borealis* is absent or minor. The lack of any significant understory cover results from the buildup and accumulation of coniferous litter.

Stands of the *Abies concolor-Pseudotsuga menziesii/Whipplea modesta* community type are found on comparatively dry sites, such as upper or midslopes of south-facing exposures or west-facing slopes near crests and ridges at various elevations. The soils are often shallow and stony, but have moderately developed A1 horizons. The stands often border those of the *Abies concolor/Linnaea borealis* community type in more mesic

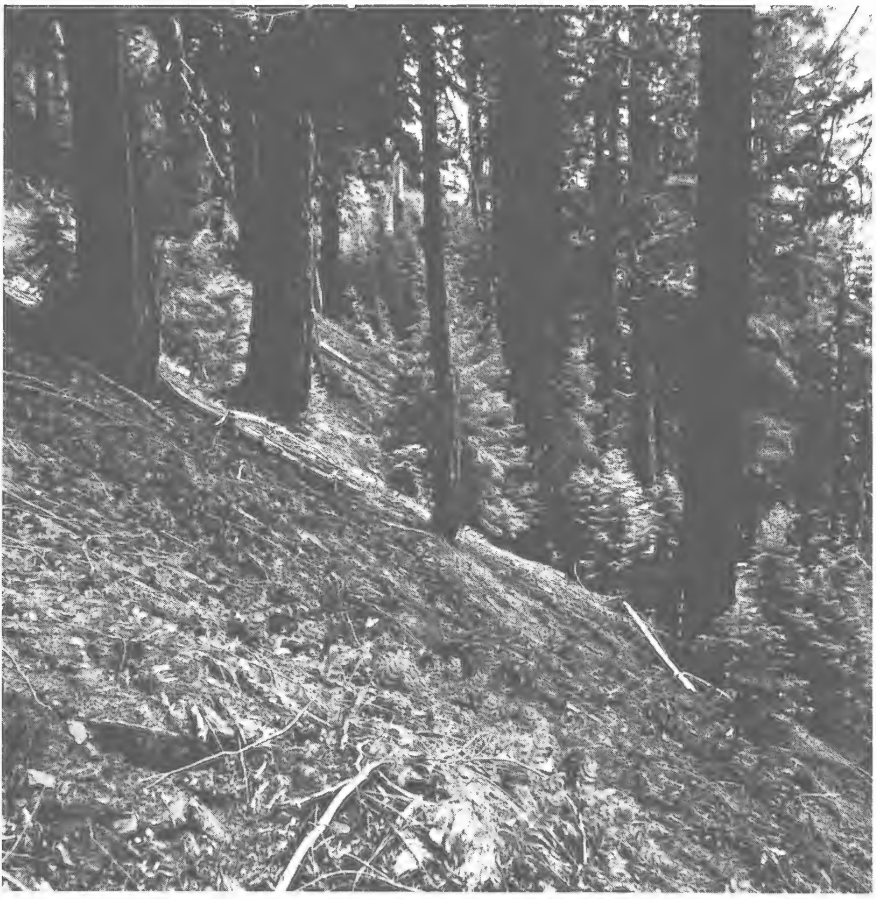

Figure 8. Young regeneration of abundant *Pseudotsuga menziesii* and *Abies concolor* under a canopy of mature *Pseudotsuga menziesii* and *Libocedrus decurrens* in plot 1 on a high elevation, east facing steep slope. The sparse understory exhibits *Whipplea modesta* in patches (*Abies concolor-Pseudotsuga menziesii/Whipplea modesta* community type).

areas and those of the *Pseudotsuga menziesii-Abies concolor/Arctostaphylos nevadensis* or *Pseudotsuga menziesii-Libocedrus decurrens/Arctostaphylos nevadensis* community types in drier sites.

5. The *Pseudotsuga menziesii-Libocedrus decurrens/Arctostaphylos nevadensis* association is represented by plots 2 and 9 located on slabby lithosols near ridge tops. *Abies concolor* is absent or minor; instead, *Pseudotsuga menziesii* and *Libocedrus decurrens* are the edaphic climax species. The forest is open, which may account for the presence here of *Pinus lambertiana* as a late seral species. *Pinus ponderosa* is represented in mature and advanced reproductive size classes. The understory features mats of *Arctostaphylos nevadensis* and *Ceanothus prostratus* which may be quite extensive (Fig. 9). On the surface of rock slabs the crustose lichens, *Lecidea atrobrunnea* and *Rhizocarpon geographicum,* are conspicuous.

Figure 9. View into plot 2. *Arctostaphylos nevadensis* dominates the ground layer and the forest is characteristically open or semi-open.

On somewhat more developed soils, this habitat has more *Abies concolor* reproduction. Also the understory tree stratum includes significant amounts of *Castanopsis chrysophylla* and *Arbutus menziesii.* We recognize this as the *Castanopsis* phase of the *Pseudotsuga menziesii-Libocedrus decurrens/Arctostaphylos nevadensis* association.

This forest habitat is the driest and subjected to the most severe summer drought intensities. Many species (*e.g., Arctostaphylos nevadensis, Ceanothus prostratus, Garrya fremontii*) are evergreen sclerophylls.

The relative position of the different community types on the ordination is significant in that it supports vegetative and topographic observations made in the field. The original or X ordination divides the plots into two groups. The first, which consists of the *Abies magnifica-Abies concolor/Ribes* spp. plots, is associated with the *Abies magnifica* var. *shastensis* zone (Dennis, 1959; Whittaker, 1960; Franklin and Dyrness, 1969). The second group consists of the other four community types described and is associated with the Mixed-Conifer zone (Dennis, 1959; Waring, 1969; Franklin and Dyrness, 1969).

The uniqueness of the *Abies magnifica-Abies concolor/Ribes* spp. community type can be attributed mainly to its location at higher elevations. All of the plots in this group are located above 5000 ft. The high elevation has a snow pack that in many instances has not melted until July. This factor is a major cause for the presence of

many species not found in the other community types and absence of other species found in these community types.

The Y axis tends to separate the four community types associated with the Mixed-Conifer zone along a moisture gradient. A similar moisture gradient has been described in other mixed-conifer or montane type forested areas of southwestern Oregon (Waring, 1969; Whittaker, 1960; West, 1966). These gradients have been designated as "topographic moisture gradients," with the more mesic sites being found in ravines and sheltered areas, while the more xeric are found on open southwest-facing slopes. The site locations along the gradient associated with the Y axis have a similar distribution. At many locations it is possible to pass down slope from an *Abies concolor-Pseudotsuga menziesii/Whipplea modesta* or *Pseudotsuga menziesii-Libocedrus decurrens/Arctostaphylos nevadensis* community type into an *Abies concolor/Linnaea borealis* and then an *Abies concolor-Tsuga heterophylla/Acer circinatum-Taxus brevifolia* community type. However, caution must be used in such generalizations. The community types infrequently extend uninterrupted over great expanses of the natural area. This fact, coupled with the rugged topography, would make the assembling of a community type map quite a formidable task.

TABLE 3. Key to the forest communities of the East Fork Abbott Creek Drainage, Abbott Creek Research Natural Area.

1. *Abies magnifica* in reproductive strata	2
1. *Abies magnifica* reproduction absent	3
2. *Tsuga mertensiana* or *Ribes binominatum* present	ABMA Complex
2. *Tsuga mertensiana* and *Ribes binominatum* both absent	3
3. *Acer circinatum* and/or *Taxus brevifolia* collectively over 10% cover	ABCO-TSHE/ACCI-TABR Association
3. Acci and Tabr both minor or absent	4
4. *Linnaea borealis* over 10% cover	ABCO/LIBO Association
4. *Linnaea borealis* less than 10% cover	5
5. *Pseudotsuga menziesii* absent in young regeneration	ABCO/LIBO, WHMO Phase
5. *Pseudotsuga* present in young regeneration	6
6. Total understory cover less than 15% and *Whipplea modesta* the most important species	ABCO-PSME/WHMO Association
6. Total understory cover often over 15%, with or without *Whipplea modesta* as a major species	7
7. *Arctostaphylos nevadensis* absent or minor	ABCO/LIBO, WHMO Phase
7. *Arctostaphylos nevadensis* dominant or codominant	8
8. *Abies concolor* over 2% reproduction; *Arbutus menziesii* often present	PSME-LIDE/ARNE, *Castinopsis* Phase
8. *Abies concolor* minor or absent	PSME-LIDE, ARNE Association

Conclusions

1. Over most of Abbott Creek Natural Area the forests will eventually be dominated by *Abies concolor*, whose dense reproduction is already apparent. At high elevations *A. magnifica shastensis* may share climax status with *A. concolor* or replace it on cooler, wetter sites. Sugar pine is a late seral species only on drier sites at lower elevations, and under present trends, will become only a minor tree in the area. The forest openings necessary for successful establishment of this and other seral species were probably brought about by fire. The role of fire in natural area management at Ab-

bott Creek needs to be given more attention if the seral forests are to be maintained or reestablished. Natural fire boundaries exist along the high ridge to the east and in the form of mesic forb communities along the divide at the north boundary.

2. The *Abies concolor-Tsuga heterophylla/Acer circinatum-Taxus brevifolia* community has high floristic similarity to several forest types of the western hemlock zone in the western Cascade Range of central Oregon (Dyrness, Franklin, and Moir, 1972; Hawk, 1972). However, the remaining forest types at Abbott Creek Research Natural Area are more similar to California Sierran forests. While these types contain important Cascadian floristic elements, they nevertheless are clearly of the *Abies concolor* and *Abies magnifica shastensis* zones, as described by Franklin and Dyrness (1969). The dominance of such evergreen sclerophyll taxa as *Ceanothus, Arctostaphylos*, or *Garrya* on drier habitats or in seral stands is suggestive of a Mediterranean type climate (mild, wet winters and hot, droughty summers) in the Cascade Range of southern Oregon.

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Vegetational Responses Following Biological Control of Hypericum perforatum in Idaho

Abstract

Hypericum perforatum L., an introduced perennial, invaded depleted grasslands of northern Idaho in the period 1920-1950 and became dominant over large areas of this region. Introduction of defoliating beetles, chiefly *Chrysolina quadrigemina* Suffr. begun in 1948 resulted in a drastic reduction in abundance of *H. perforatum,* generally in two to three years after release of the beetles on a site. Following the initial reduction, fluctuations in populations of both *H. perforatum* and *C. quadrigemina* have been recorded over a 15 year period. In each case, increases in the population of the plant have been followed within a year or two by a corresponding increase in beetle populations and a subsequent decline in abundance of *H. perforatum.* Thus, a continuing predator-prey relationship appears to have been established in which the overall abundance of *H. perforatum* fluctuates around an amount estimated at about 3 percent of that present in 1948.

Introduction

One of the most conspicuous and abundant invaders of far western rangelands during the first half of this century was *Hypericum perforatum* L., variously known as St. Johnswort, goatweed, or Klamath weed. This perennial forb, a native of southern Europe, reached California about 1900, and subsequently spread over sizable areas of that state, Oregon, Washington, Idaho, and western Montana. In Idaho it had become sufficiently abundant by 1930 in the Clearwater and Salmon River drainages to cause concern, and its spread accelerated during the next two decades. At its peak, *H. perforatum* was reported to infest some 2 1/3 million acres in California (Huffaker and Kennett, 1959) and 1,217,000 acres in the Columbia Basin (Columbia Basin Noxious Weed Control Task Force, 1952). Included in the total was an estimated 615,000 acres in Idaho. This species had also become an important range weed in Australia (Wilson, 1943).

H. perforatum was first considered undesirable as a plant poisonous to livestock. The plants contain two substances, hypericin and hypericum red, which are capable of poisoning by photosensitization (Muenscher, 1951). Death of livestock due to eating the plant is rare, but serious losses in weight and condition of livestock have been reported (Marsh and Clawson, 1930). The palatability of the species to cattle or sheep is low, however, and it is eaten in significant amount only when there is a severe shortage of more desirable forage. Thus the major role of *H. perforatum* is that of an aggresive range weed whose presence in large amounts greatly reduces the grazing capacity of infested areas.

After unsatisfactory attempts at control of *Hypericum* by chemical means, biological control efforts using beetles of the genus *Chrysolina* fam. *Chrysomelidae* were initiated in California in 1946 (Holloway and Huffaker, 1951). Like St. Johnswort, these beetles are native to Europe, but were brought to the United States from Australia, where bio-

logical control of St. Johnswort had already been initiated (Wilson, 1943). The two species originally introduced into the United States were *Chrysolina quadrigemina* Suffr. (*C. gemellata* Rossi) and *C. hyperici* Forst. These defoliating insects feed only on *H. perforatum* and a few ornamental species of this genus (Smith, 1958). Initial success of the control program in California led to a program of beetle releases in Idaho, starting in 1948. Cooperative studies of the various species of beetles introduced and of the responses of *H. perforatum* and associated vegetation were undertaken by the staff of the Departments of Entomology and Agronomy (Plant Science) of the College of Agriculture and the Range Management section of the College of Forestry, Wildlife, and Range Sciences. Data on the ecology of *H. perforatum* were published earlier (Tisdale *et al.,* 1959). Information on the changes in vegetation resulting from the effects of *Chrysolina* beetles on the grassland portion of the infested area is presented in the present paper. Results of the biological control program in the forest areas of the state will be published as soon as a final assessment in the field is completed. These vegetational sudies were conducted mainly during the period 1951-1958. By that time biological control appeared to be successful over the greater part of the grassland area in Idaho. Observations were continued on a smaller scale through 1970. These later studies were made chiefly to determine the nature of the relationship established between greatly reduced populations of *H. perforatum* and of *Chrysolina* beetles. It seemed desirable to obtain this type of information since the only comparable studies in North America were those reported by Huffaker and Kennett (1959) in California, and Harris *et al.* (1969) in British Columbia.

These investigations were conducted in the northern part of the State, *i.e.,* north of the Salmon River (Fig. 1). Virtually all of the *Hypericum* infestations were confined to that portion of the state, which differs considerably in climate and vegetation from the southern part. The characteristics of the study area have been described previously (Tisdale *et al.,* 1959), and only a few points of special significance are presented here.

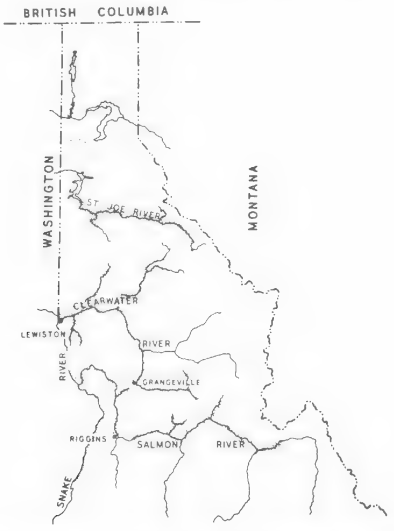

Figure 1. Sketch map of study area showing distribution of *Hypericum perforatum* in 1951.

The grassland area of northern Idaho is confined primarily to the valleys of the Snake and Salmon Rivers and their tributaries. The climax dominants are *Agropyron spicatum* (Pursh.) Scribn and Smith and *Poa sandbergii* Vasey at lower elevations and *A. spicatum* and *Festuca idahoensis* Elmer at higher altitudes. Most of the grassland on areas of relatively smooth topography has been brought under cultivation. The remainder is used primarily as spring-fall range for livestock and winter range for big game. Severe grazing pressure in the early 1900's depleted much of this range and brought about dominance by annuals, including several introduced species of *Bromus*. While the total area of this grassland is only about one million acres, its situation at relatively low elevations and in areas of mild winter climate makes it highly important as a grazing resource (Evans and Tisdale, 1972).

The majority of the *H. perforatum* infestation in Idaho has been in the grassland region. This invader proved well adapted to the grassland environment, and able to invade rapidly areas of depleted range supporting an annual cover. A fairly wide range of climates was involved, with average annual precipitation varying from 300 to 600 mm (12 to 24 in). The general climatic pattern of the region is marked by precipitation occurring mainly in winter and by warm, dry summers (Table 1).

Methods

Permanently located sample plots were established during 1951 and 1952 in order to determine the nature of the current vegetation and to record changes that might occur as a result of the action of the introduced *Chrysolina* beetles. Each group of plots was established on the site of a beetle release, in a stand representative of the surrounding vegetation, and infested with *H. perforatum.* This latter criterion was not difficult to satisfy, since the infestation by this weed was widespread. Twenty sites were established, covering the full geographical range of the study area, but with some concentration in the most heavily infested areas, in the drainages of the Lower Snake, Clearwater, and Salmon rivers. These sites included a variety of topographical situations and occurred at elevations from 1200 to 4000 ft above sea level, although most were situated below 3500 ft. Several sites were subsequently damaged by cultivation or fire, and a few proved to be atypical of large areas. Eventually nine sites were chosen for continued monitoring.

Sampling of the vegetation in 1951 was based on five permanently marked plots 0.5 by 1.5 m in size at each site. These plots were established by means of a metal frame divided into five subsections by cross wires and supported by four adjustable legs. The frame and cross wires were notched at one dm intervals to guide the placing of a 19 mm (3/4 in) loop fixed on a long rod. This operation provided for use of a modified form of the loop transect method (Parker, 1951; Sharp, 1954). Density of *H. perforatum* plants was determined on these same plots.

The permanent sample plots were laid out from a center at actual beetle release sites on a line determined by randomly drawing one of the group of 5° compass bearings available on the site. The distance from the center to the first plot was determined by a random number between 1.5 and 30.5 m. Additional plots were located at intervals of 30.5 m along this line.

This method provided intensive sampling of the plots established, but was slow and gave only limited coverage of each site. A more rapid method was initiated in 1952,

TABLE 1. Precipitation in millimeters by crop years (Sept.-Aug.) for 2 representative stations in the study area, 1952-1966.

STATION	CROP YEAR															MEAN
	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	
Lewiston	309	310	279	232	525	313	320	379	309	326	299	309	303	405	181	320
Riggins	472	397	367	322	559	456	374	417	531	336	424	476	447	488	276	423

using a 2 by 2.5 dm frame to obtain frequency of all species, as well as density of *H. perforatum* plants. The frame also contained a built-in 19 mm loop to obtain data by this method. Fifty plots were sampled at three pace intervals along each of three permanently marked lines laid out in a restricted random design from the beetle release center.

The frequency/count transects were used to supplement the permanent plots on sites established in 1951, and this method was the only sampling procedure on sites established subsequent to 1951.

Annual herbage weight was obtained by clipping all vegetation to ground level in ten plots 1 by 0.5 m in size, located systematically along a line 3 m from randomly selected sides of the transect lines. Clippings were dried to 6 percent moisture content. If a plot area selected for clipping showed signs of grazing use during the current year it was replaced by the next closest ungrazed area on that line.

No counts of *Chrysolina* populations were made at the study sites, but estimates were made of the amount of defoliation which they accomplished. This damage was easily observed since it was completely selective for *Hypericum.*

Results

The responses of *H. perforatum* and associated vegetation to the effects of *Chrysolina* beetles are summarized for nine sites for which long-term records were obtained. The vegetation of these sites was sufficiently similar to warrant treating them as one group for the purposes of the present study. Although *Chrysolina hyperici* were released at a few sites, *C. quadrigemina* proved better adapted to the grassland region and was responsible for virtually all of the reduction of *H. perforatum* reported.

The study areas considered individually are those for which data were obtained during years when no general resampling was done. The objective in this case was to determine the extent of annual fluctuations occurring in populations of *H. perforatum* exposed to the *Chrysolina* beetles.

Average Response of Grassland Sites

Herbage yield, species frequency, and basal cover indices by species or plant groups and frequency and density of *H. perforatum* seedlings were obtained for nine sites in the years indicated.

Herbage yields. The data are summarized in Figure 2. They indicate the rapid decrease in yield of *H. perforatum* which occurred during the period 1952-54, and a further more gradual drop by 1958. The longer term trend of populations of this species is shown by data on other characteristics of the plant cover.

Yields of annual grasses and of forbs (mostly annuals) increased as *H. perforatum* decreased, although total yields in 1955, 1954, and 1958 were below those of 1952 and 1953. This difference appears due to a combination of factors. Annual precipitation was below average in the study area in 1954 and 1955, though not in 1958. Another factor may have been the effects of early spring grazing on the grasses and forbs which comprised an increasing proportion of the annual plant production as the abundance of the *H. perforatum* was reduced by the beetles. Although areas showing obvious grazing use were not included in the yield samples, there was probably some early utilization, since none of the study sites was actually protected from grazing.

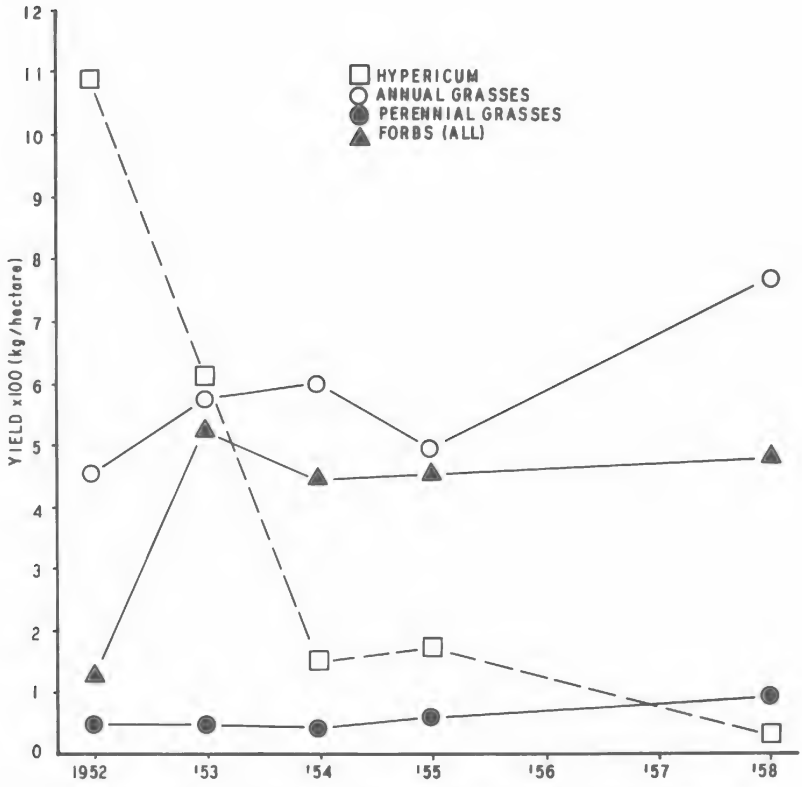

Figure 2. Average herbage yields for nine *Hypericum perforatum* study sites, 1952-1958.

The annual grasses consisted mainly of introduced species of *Bromus,* chiefly *B. tectorum* L., *B. brizaeformis* Fisch and Mey, *B. mollis* L., and *B. japonicus* Thunb. The other principal annual grass was *Festuca megalura* Nutt. *Taeniatherum asperum* (Sim.) Nevski (syn. *Elymus caput-medusae* L.), a comparatively new arrival in the study area, invaded five sites in the Snake River and Clearwater drainages during the course of the study.

Yields of all forbs were grouped during the earlier years of the study, but annual and perennial species were separated in 1958. This separation showed that annuals composed the greater part of the forb yield, constituting an average of 79 percent of total forb production in that year. Frequency and basal area index data indicated a gradual increase in the relative importance of perennial forbs during the study period.

The most common perennial forbs were native species including *Achillea millefolium* Nutt., *Agoseris grandiflora* (Nutt.) Greene, *Balsamorhiza sagittata* (Pursh) Nutt., *Lomatium triternatum* (Pursh) and R., *L. dissectum* (Nutt.) M and C., *Lupinus laxiflorus* Nutt., and *L. leucophyllus* Dougl. The principal annual forbs included *Amsinckia retrorsa* Suksd., *Ambrosia artemisiaefolia* L., *Epilolium paniculatum* Nutt., *Erodium cicutarium* (L.) L'Her., *Helianthus annuus* L., *Lactuca serriola* L., and *Stellaria nitens* Nutt. A biennial, *Tragopogon pratensis* L., was also abundant on many sites.

The average yield of perennial grass per site was low compared to that of annual grasses and forbs, but increased slowly during the study period. Little of this production came from native climax species such as *Agropyron spicatum* or *Poa sandbergii.* Most of it was provided by *Poa pratensis* L., an introduced grass which spread primarily by vegetative means on four sites located in the Salmon River drainage. One site, situated at a low elevation near the Snake River, had a considerable stand of *Aristida longiseta* Steud., an unpalatable native grass which has increased greatly due to heavy spring grazing in portions of the study area (Evans and Tisdale, 1972). Four sites in the northern part of the study area remained virtually devoid of perennial grasses throughout the 1952-1970 period.

Frequency data. The results are summarized in Figure 3. The trends are similar to those shown by the herbage yields, but have the advantage of sampling over a longer period and the separation throughout of annual from perennial forbs. With the exception of *H. perforatum,* the data represent pooled frequencies of species in each class. The marked decline in *H. perforatum* is evident, although to a lesser degree than shown by the yield data. The marked increase in annual grasses and annual forbs and the lesser increase in perennial grasses and perennial forbs are also shown clearly.

Additional conclusions arising from the frequency data are that (a) populations of *H. perforatum,* although greater at times than the low level reached in 1958, did not become nearly as large in either 1963 or 1966 as in the early years of the study; (b) annual grasses and annual forbs, although reduced in frequency by shortage of precipitation in 1966 (the driest year of the study period), dominated the plant cover even in the last year of sampling; (c) *Taeniatherum asperum* continued to increase on four sites and reached a position of dominance on two of these by 1966; (d) *Poa pratensis* continued its increase, with average frequency on the sites involved rising from 5 percent in 1952 to 17 percent in 1958 and 27 percent in 1966.

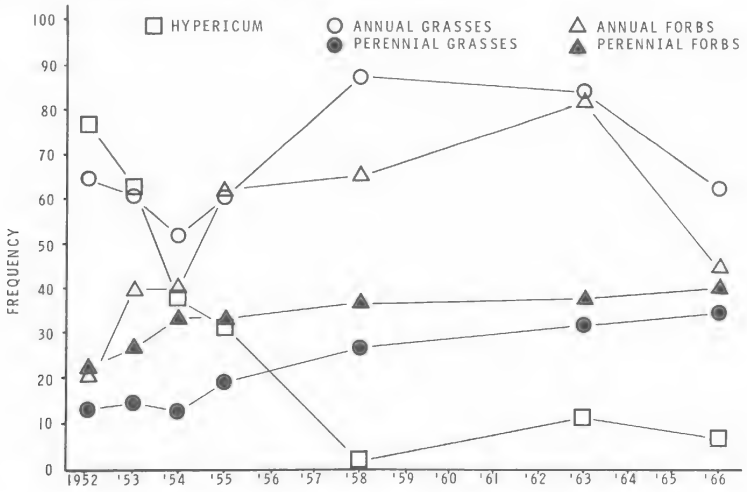

Figure 3. Average frequency of *Hypericum perforatum* and associated vegetation, 1952-1966. Pooled frequencies for annual grasses and for annual forbs have been divided by three; pooled frequencies for other vegetation classes have not been adjusted.

Basal area index. These data (Table 2) were taken only during the period 1952-58, and add little of significance to the information furnished by yield and frequency sampling. The marked decline in cover of *H. perforatum* and an increase in that of annual grasses and forbs is evident; so, too, a lesser increase in perennial grasses and forbs. The relative importance of annual grasses and forbs appears to be over-estimated by the loop method, a bias demonstrated by Hutchings and Holmgren (1959). The basal cover index for total vegetation was relatively high, and remained so throughout the period. Live vegetation plus a cover of litter, which averaged 40 percent, provided a total cover which appeared to provide ample soil protection on all study sites.

TABLE 2. Basal area index* of vegetation on 9 sites infested by *Hypericum perforatum,* 1952-58.

	Year of Sample				
Species or Class	1952	1953	1954	1955	1958
Hypericum perforatum	10.4	6.7	3.7	2.2	2.1
Annual Grasses	30.4	26.4	22.0	20.5	30.6
Perennial Grasses	2.6	3.2	3.6	4.6	5.6
Forbs	4.0	9.1	15.7	10.7	15.7
Total Vegetation	47.4	45.4	45.0	38.0	53.9

* Data obtained with 19 mm loop.

Seedling data. Frequency and density of *H. perforatum* seedlings were obtained at all sites throughout the major study period. The results are summarized in Table 3. Substantial numbers of seedlings were present on some study sites in five of the seven years when samples were taken, and were abundant on six sites in 1958, and on four in 1963. No live seedlings were found during the exceptionally dry summer of 1966. Earlier results from this project (Tisdale *et al.,* 1959) show that high mortality of *H. perforatum* seedlings is common in the study region as a result of deficiency of precipitation during the time of highest temperatures in July and August. On the other hand, our studies and those of Bellue (1945) and Clark (1953) have documented the abundant seed production of this species and the fact that its seeds can remain viable in the soil for three to ten years.

TABLE 3. Density and frequency of *Hypericum perforatum* seedlings on 9 sites, 1952-1966.

	1952	1953	1954	1955	1958	1963	1966
Density/m^2	16.1	0.3	1.7	3.0	87.6	22.8	0
Frequency %*	8	T	6	8	44	19	0

* Frequency determined on 2.0 x 2.5 dm plots.

The significant fact in the present case is that seedlings of *H. perforatum* continued to appear on the study sites over a period during which most of the mature plants were deprived of normal seed production by the depredation of *Chrysolina* beetles. The answer seems to lie in a combination of two factors—first, some plants invariably escaped the action of the beetles and produced seed, especially in years when both plant and beetle populations were sparse; secondly, sufficient *H. perforatum* seed probably remained in the soil to provide seedling populations when favorable conditions occurred.

Hypericum population trends on key sites. In addition to the sampling reported in the previous section, sampling and/or observations were made on several sites during other years in the interval between 1958 and 1970. On four of these, located in the lower Clearwater and Snake River Valleys, sampling for frequency was done four additional years, and observations made in four other years. In years when no detailed sampling was done, an estimate of the relative amount of *H. perforatum* was made by walking several transects across each site and comparing the current amount of this species with the dried stems from the previous year.

Results for the four sites are shown in Table 4. They indicate that there were two brief upsurges in the population of this species, one in 1959 and another in 1968-69. No detailed data are available for the second period of increase, but counts of dead stalks made in 1970 indicated that the population attained in 1968-69 was lower than that of 1959.

Chrysolina quadrigemina activity showed a close relationship to *H. perforatum* populations. Damage by beetles was low in 1958, but much higher in 1959, with severe defoliation observed. Damage by the beetles was strong on the reduced populations of *H. perforatum* in 1960 and 1961, but few beetles and little damage were evident in 1962 through 1965. Beetle effects were also limited in 1966, but may have increased considerably during 1968 or 1969 judging by the large number of dead plants observed in 1970. Observations made at the other six sites indicated a similar sequence to that described above, although not always occurring at the same level of *H. perforatum* or *C. quadrigemina.* Fairly stable predator-prey relationships appeared to be operating, with beetle numbers increasing just behind increases in *H. perforatum* and preventing the latter from attaining large populations.

Discussion and Conclusions

The data presented indicate that a massive reduction in *Hypericum perforatum* populations has been achieved in the study region since 1950 by the introduction of *Chrysolina* beetles, chiefly *C. quadrigemina.* The major part of this reduction usually came within two to three years after release of the beetles on a site. By 1970, *Hypericum* populations had been reduced to an estimated 3 percent or less of the population which occurred prior to the release of beetles (Fig. 4A, B, C).

The pattern that has developed in this biological control program is marked by considerable fluctuation of *H. perforatum* numbers, but a level far below that of populations prior to the release of *Chrysolina* beetles. Significant population increase of the weed occurred at least twice during the period 1958-1970, but in each case this was reversed by beetle populations which increased in a parallel manner to that of *H. perforatum,* but one to two years later. It appears that a new balance has been established for *H. perforatum,* in which a low population is maintained primarily by the action of *Chrysolina quadrigemina.*

The drastic reduction in amount of *H. perforatum* has been largely offset by the same seral species which dominated prior to the invasion of *Hypericum* populations. These seral species consist mainly of introduced annual grasses, including several species of *Bromus,* along with a lesser amount of annual forbs both native and introduced. One introduced annual grass, *Taeniatherum asperum,* invaded a sizable portion of the

TABLE 4. Frequency of *Hypericum perforatum* plants on 4 sites in the lower Snake-Clearwater Valleys, 1958-70.

	YEAR OF RECORD												
SITE	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
1	6	48	4	8	3	0	very low	very low	26	low	upsurge	upsurge	8
1A	4	59	4	2	0	1	very low	very low	2	low	upsurge	upsurge	2
3	6	42	7	1	0	2	very low	very low	9	low	upsurge	upsurge	7
3A	2	51	21	9	3	8	very low	very low	7	low	upsurge	upsurge	1
Mean	4.5	50	9	5	1.5	2.7	very low	very low	11	low	upsurge	upsurge	4.5

study area during the period 1952-70, and has become dominant on two of the nine study sites.

Perennial grasses and forbs increased slowly from a low initial base during the study period. Perennial forb increase occurred mainly among native species of *Achillea,*

Figure 4A. Site in lower Clearwater drainage infested by *Hypericum perforatum* in 1952. Note dense stand of the weed on major part of site.

B. Same site 1954 showing great reduction in amount of *H. perforatum.*

C. Same site in 1963 showing continued control of *H. perforatum. Taeniatherum asperum* has invaded and become dominant.

Balsamorhiza, Lomatium, Lupinus, etc. The perennial grass situation is different, since most of the increase occurred in *Poa pratensis,* an introduced rhizomatic species which occurred on only four of the nine study sites in the grassland area. *Agropyron spicatum,* the principal climax dominant for the grassland region, had been severely reduced on all of the study sites prior to their invasion by *H. perforatum.* The failure of this species to make significant increases during the study period appears due mainly to an extremely limited seed source within an effective distance of most sites, and strong competition which its seedlings encounter from *Bromus tectorum* and other annual grasses (Harris, 1967; Harris and Wilson, 1970).

From the viewpoint of range improvement, a significant forage increase has been achieved by the biological control of *H. perforatum,* since this species is less palatable than most of the annuals which have replaced it. In addition, it has a potential as a poisonous plant under conditions of overstocking (Fig. 5A, B, C).

The return of this vegetation to perennial grassland, however, will require more than the reduction of *Hypericum* populations. Natural recovery of *A. spicatum* is inhibited by inadequate seed source, competition from annual grasses, and continuing heavy grazing use on many sites. A return to dominance of perennial grasses within a reasonable time will require improved grazing management to increase the cover and production of *Poa pratensis* on sites where it is adapted. The remaining areas need artificial reseeding, where feasible, to species such as *Agropyron desertorum* (crested wheatgrass) which is superior to *A. spicatum* for establishment in stands of annual bromes and medusahead (Harris and Wilson, 1970).

In conclusion, it appears that biological control of *Hypericum perforatum* by *Chrysolina quadrigemina* in the study area is an established fact. Replacement has been mainly by annuals. These, however, constitute communities which are open to inva-

sion by introduced species. Two invaders have already appeared: one, *Poa pratensis,* a desirable perennial; the other, *Taeniatherum asperum,* an undesirable annual. Control

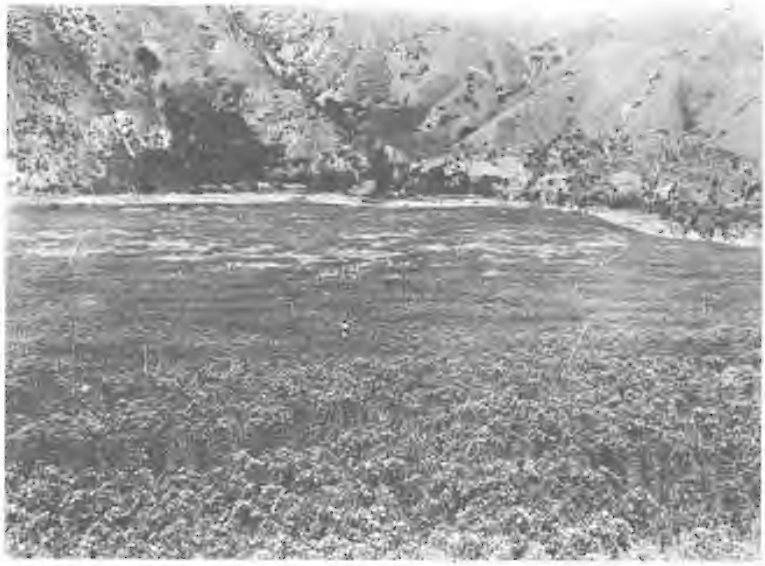

Figure 5A. Site in lower Salmon River Valley near Riggins, heavily infested with *Hypericum perforatum* in 1951. Meter stake marks location of a sample plot.

B. Same site in 1955 showing marked reduction in amount of *H. perforatum.*

C. Same site in 1963 showing continued control of *H. perforatum.*

of *H. perforatum* has not solved the problem of unstable communities. In this respect the biological control program in Idaho and other areas of the Pacific Northwest may not be as satisfactory as in parts of California where Huffaker (1951) has reported significant increases in *Danthonia californica,* a native perennial grass, as a consequence of the reduction in *H. perforatum* populations.

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Dr. W. F. Barr, Professor of Entomology, University of Idaho, supplied valuable information regarding the insects involved as predators on *Hypericum perforatum.*

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A Survey of Fishes of the Clearwater River

Abstract

The distribution of fishes of the Clearwater River in north central Idaho was studied. Nineteen fish species were collected. These species were *Salmo gairdneri, Salmo clarki, Salvelinus fontinalis, Salvelinus malma, Oncorhynchus tshawytscha, Prosopium williamsoni, Ptychocheilus oregonensis, Acrocheilus alutaceus, Rhinichthys osculus, Rhinichthys cataractae, Richardsonius balteatus, Catostomus columbianus, Catostomus macrocheilus, Lampetra tridentata, Micropterus dolomieui, Cottus bairdi, Cottus rhotheus, Cottus beldingi,* and *Cottus confusus.*

Introduction

During 1969-71, information was collected on the distribution of fish in the Clearwater River system in north central Idaho. Emphasis was placed on the distribution of cottids but data on other species were collected. Little previous systematic collecting has been done in this area; therefore, little is known about the distribution of fishes inhabiting the system. The following paper is a treatment of the fish distribution data collected during this study.

Description of Study Area

The Clearwater River system, draining the north central part of Idaho (Fig. 1) lies between the Salmon River on the south, the Palouse and St. Maries Rivers on the north, and the Clark Fork and Pend Oreille Rivers on the north and east. The total drainage area is 9600 square miles with an average runoff of 11,300,000 acre-feet (U.S. Forest Service, 1969). The elevation varies from 715 ft at Lewiston, Idaho, to nearly 9000 ft along the eastern boundary in the Bitterroot Mountains.

Precipitation is variable over the drainage and mainly concentrated in the early spring and fall. Peak flows usually occur in March through June, and low flows are reached in August and September prior to the fall rains. The major streams in the drainage are the Lochsa, Selway, North Fork Clearwater, South Fork Clearwater, and main Clearwater (Fig. 1).

The geology of the area is poorly known. Generally, streams flow through Idaho batholith in the upper part of the drainage, and through Columbia River basalt or schist and gneiss in the lower portion (Ross and Forrester, 1958).

Methods and Materials

Fish were collected with a backpack electro-shocker and a 6-foot seine. The method of collection was as follows: A small Y net (Bond, 1963) or a seine was set or held in the river or stream downstream from the area to be sampled. The shocker operator

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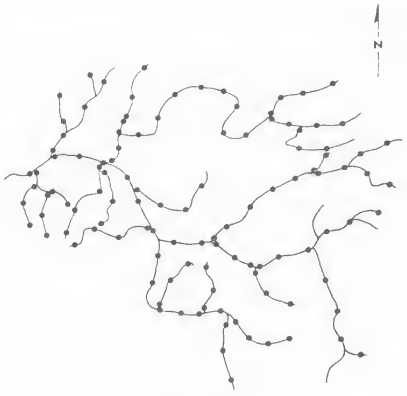
entered the stream upstream from the net and moved downstream shocking the area between his point of entry and the net. As the shocker operator moved through the area, he overturned rocks and disturbed the substrate with his feet. A slight pause upon reaching the net allowed stunned fish to drift into the net; then the net was lifted from the water. This method of capture was extremely efficient for smaller fishes, especially cottids, but large, mobile fishes may have avoided the shocker. In the Selway Bitterroot Wilderness Area, the seine was set and the area directly above the net was disturbed as described by Bond (1963). The change in collecting technique was necessitated because Mr. Edward Slusher, Chief, Special Areas Branch Recreation and Lands, Forest Service, Region 1, Missoula, Montana, ruled that only a 6-foot seine could be used in the wilderness area. Depths of over 6 feet were impossible to sample with this equipment. Within these depth constraints, both riffles and pools were sampled. Collections were taken from 114 (Fig. 2) locations spaced at about

Figure 1.



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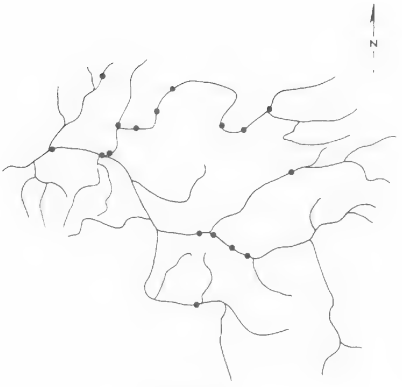

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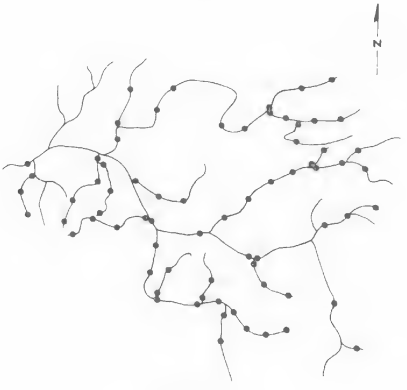


Figure 4.

Figure 1. The Clearwater drainage in north-central Idaho. Figure 2. Approximate location of collecting sites in the Clearwater drainage. Figure 3. Sites in the Clearwater drainage where lamprey ammocetes were collected. Figure 4. Sites in the Clearwater drainage where rainbow trout were collected.

10-mile intervals throughout the drainage. Collecting periods were restricted to June through September 1969 and 1970 and restricted to daylight hours. Electrofishing units and particularly backpack units become increasingly inefficient as the size and the depth of the water increase. In addition, more active vagile fishes are commonly scared away from the collecting area, before they are shocked, by the activity associated with electrofishing. Therefore, distributions of larger more vagile fishes presented may be conservative. The data can only be viewed as the results of two summers of collecting and must be interpreted within the limits of the collecting equipment.

Results and Discussion

Lampetra tridentata—Pacific Lamprey.
This species is found along the Pacific coast and inland into freshwater (Eddy, 1969). Pacific lamprey are non-parasitic in freshwater but become parasitic after migrating into the sea.

The lamprey was taken from 17 widely scattered Clearwater locations generally over sandy bottomed areas (Fig. 3). One hundred ammocetes were taken during the study. These specimens were tentatively identified as *Lampetra tridentata.*

Salmo gairdneri—Rainbow Trout.
Rainbow or steelhead trouts were originally found in the western U.S. in streams draining to the Pacific downstream from falls or other barriers to migration. *Salmo gairdneri* was taken throughout the Clearwater with the exception of Potlatch River (Fig. 4). The absence of *Salmo gairdneri* from Potlatch River may have been the result of pollution (M. J. McMasters, Idaho Department of Water Quality and Health, pers. comm.) or the result of intermittent flows. No attempt was made to separate the subspecies of *Salmo gairdneri.*

Steelhead trout is the most popular game fish in this area. Fisheries personnel are attempting to maintain and, if possible, increase steelhead production.

Salmo clarki—Cutthroat Trout.
Salmo clarki was originally represented by distinct morphological subspecies in each of the western basins. Most of these subspecies have either been eliminated or have decreased in abundance because of degradation of the environment or introduction of competing species. Degradation of the environment has resulted from agricultural and industrial pollution, deterioration of watersheds from logging and farming practices, and placement of dams and other barriers to migration and reproduction (Sigler and Miller, 1963). The west slope cutthroat, the subspecies native to the Clearwater (unpublished studies by Behnke and Behnke and Wallace) (R. L. Wallace, The University of Idaho, pers. comm.), may be an endangered subspecies.

Cutthroat were located at the extreme headwaters areas of the Clearwater (Fig. 5). Cutthroat apparently spawn and rear in very small headwater tributaries, then migrate to the larger rivers (Ball, 1971).

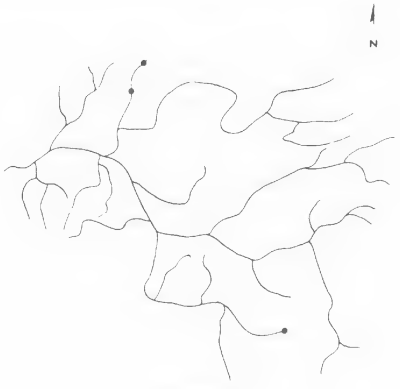
Salvelinus fontinalis—Brook Trout.
The brook trout is a species native of the Northeast and the Appalachian Mountains (Eddy, 1969) that has been widely introduced in the western United States. This trout has been very successful in some areas of Idaho but rarely occurred in my collections from the Clearwater (Fig. 6). Brook trout were taken from Elk Creek

(North Fork Clearwater) and Red River (South Fork Clearwater). Brook trout of all sizes were taken on Elk Creek. A single specimen of *Salvelinus fontinalis* was taken from the Red River about one-half mile below Red River Hot Springs.

Salvelinus malma—Dolly Varden.

The Dolly Varden or bull trout is known from northern California to western Alaska (Carl *et al.*, 1967). Dolly Varden were rare (Table 1) in my collections from the Clearwater (Fig. 15). One specimen was taken from Newsome Creek in my regular collections. A second specimen was obtained from Silver Creek (South Fork Clearwater). Silver Creek was not one of my scheduled collections. Newsome Creek in the area of collection was a small sand and gravel-bottomed creek containing a large amount of deadfall. Silver Creek was a high gradient stream composed of a series of falls. Anglers reported that Dolly Varden were found in other rivers of the drainage.

Figure 5.



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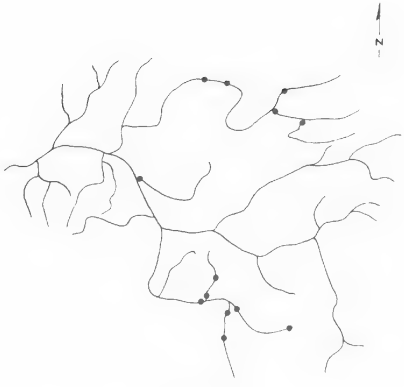

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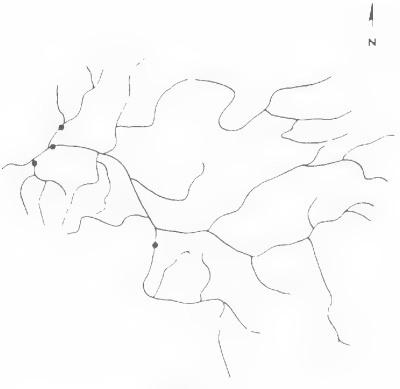


Figure 8.

Figure 5. Sites in the Clearwater drainage where Cutthroat trout were collected. Figure 6. Sites in the Clearwater drainage where brook trout were collected. Figure 7. Sites in the Clearwater drainage where mountain whitefish were collected. Figure 8. Sites in the Clearwater drainage where chiselmouth were collected.

TABLE 1. Species list and relative distribution of Clearwater fishes.

Species List for Clearwater	Number of Collection Sites at Which This Species Occurred	Percentage of Sites at Which This Species Occurred
Salmo gairdneri (rainbow and steelhead trout)	75	62.5
Cottus beldingi (piute sculpin)	63	52.5
Rhinichthys osculus (speckled dace)	52	43.3
Rhinichthys cataractae (longnose dace)	46	38.3
Cottus rhotheus (torrent sculpin)	40	33.3
Cottus bairdi (Columbia River mottled sculpin)	38	31.7
Catostomus columbianus (Bridgelip sucker)	27	22.5
Ascaphus truei (tailed frog)	27	22.5
Cottus confusus (shorthead sculpin)	25	20.8
Lampetra tridentata (Pacific lamprey)	19	15.8
Richardsonius balteatus (redside shiner)	17	14.2
Prosopium williamsoni (mountain whitefish)	13	10.8
Ptychocheilus oregonensis (Columbia River squawfish)	9	7.5
Salmo clarki (cutthroat trout)	7	5.8
Acrocheilus alutaceus (chiselmouth)	4	3.3
Salvelinus fontinalis (brook trout)	4	3.3
Micropterus dolomieui (smallmouth bass)	4	3.3
Catostomus macrocheilus (largescale sucker)	2	1.7
Oncorhynchus tshawytscha (chinook salmon)	2	1.7
Salvelinus malma (Dolly Varden trout)	1	0.9

Oncorhynchus tshawytscha—Chinook Salmon.

The chinook salmon is a species that spawns in many streams in the northwestern United States. During the late 1920's, a hydroelectric dam constructed near Lewiston, Idaho, eliminated the runs from the Clearwater. The Idaho Fish and Game Department began a program in 1947 to restore these runs. The hydroelectric dam was removed and manmade spawning channels were constructed at Running Creek and Ditch Creek on the Selway River as part of the restoration program. The program has been a limited success (Welsh, 1963).

Chinook were seen on a riffle at White Cap Creek in September 1970. A dead chinook was also seen on Moose Creek 20 mi above the mouth (Fig. 15).

Prosopium williamsoni—Mountain Whitefish.

The mountain whitefish is a species found on the west slope of the Rockies from British Columbia to Nevada and east of the Continental Divide in the headwaters of the Missouri and South Saskatchewan Rivers (Carl *et al.,* 1967; Blair *et al.,* 1968). This species is an abundant schooling fish found in trout streams. Competition for food and nesting areas between trout and mountain whitefish may lead to a decrease in the quality of the trout fishery (Sigler and Miller, 1963).

Mountain whitefish were taken from the South Fork and North Fork Clearwater Rivers and the mouth of Lolo Creek (Fig. 7).

Acrocheilus alutaceus—Chiselmouth.

The chiselmouth is a species restricted to the Columbia and Fraser River systems (Carl *et al.,* 1967). Little is known of chiselmouth life history.

Acrocheilus was taken from three sites near the mouth of the Clearwater and one

site at the mouth of the South Fork Clearwater (Fig. 8). A single specimen was taken at the mouth of the South Fork Clearwater and represented the extent of the upstream distribution for my collections.

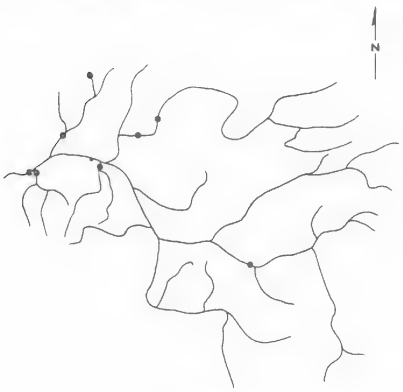
Ptychocheilus oregonensis—Northern Squawfish.

The northern squawfish is a species found in the Columbia, Skeena, and Nass systems in Washington and British Columbia (Carl *et al.,* 1967). Squawfish are considered important competitors and predators of trout.

Squawfish were generally found in the lower one-half of the drainage. Specimens were not taken from most tributaries or in the upper portions of the drainage (Fig. 9).

Rhinichythys cataractae—Longnose Dace.

The longnose dace is found coast to coast in North America and east of the Rocky



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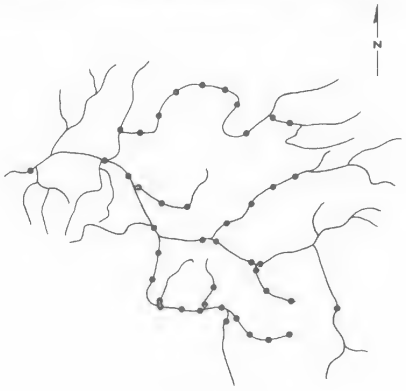

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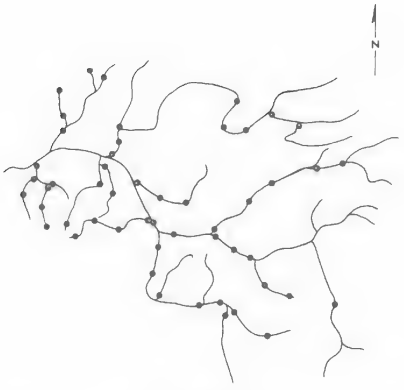

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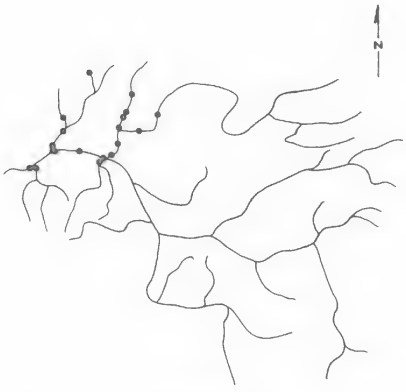


Figure 12.

Figure 9. Sites in the Clearwater drainage where northern squawfish were collected. Figure 10. Sites in the Clearwater drainage where longnose dace were collected. Figure 11. Sites in the Clearwater drainage where speckled dace were collected. Figure 12. Sites in the Clearwater drainage where redside shiners were collected.

Mountains as far south as Mexico (Carl *et al.,* 1967). Very little is known of its habits despite the wide range.

Longnose dace did not show the morphological variation that was characteristic of the speckled dace. Only a few longnose dace were taken from each location. These data suggested that *Rhinichythys cataractae* was a solitary, non-schooling fish.

Rhinichythys cataractae was absent from the extreme headwater areas in the Clearwater and most of the smaller tributaries (Fig. 10). The reasons for these absences were unknown.

Rhinichythys osculus—Speckled Dace.

The speckled dace is a schooling species found in the Columbia and Colorado systems (Eddy, 1969). There is a great deal of morphological variation within this species and *Rhinichythys osculus* as now recognized may represent an aggregation of several species. Confusion also exists in the identification of *Rhinichythys osculus* and *Rhinichythys falcatus.* These two species are morphologically similar and may represent ecological variants of the single species. A detailed study of the *Rhinichythys osculus-Rhinichythys falcatus* complex is needed to resolve the taxonomic problems.

Clearwater populations varied greatly from one another. Breeding adults from Middle Potlatch Creek averaged less than two inches in length. Breeding adults from the mouth of Elk Creek were commonly four to six inches long. Size variation existed throughout the drainage. Smaller individuals were generally found in smaller streams. Color also varied from location to location. Color variation was closely related to substrate color. The fish were brown to blackish gray and lacked spots and splotches when found over a mud or algae-covered bottom. Fish had golden speckles and blotches where the bottom was golden.

The speckled dace was found from lowland tributaries to typical trout waters. However, the species was absent from the extreme headwater areas (Fig. 11).

Richardsonius balteatus—Redside Shiner.

Richardsonius balteatus is a species found throughout the western basins in a wide variety of habitats. Highest densities occur in cool, slow rivers (Sigler and Miller, 1963).

Redside shiners were restricted to the lower one-third of the main Clearwater and tributary streams which enter the river from the north (Fig. 12). The habitat occupied varied from large pools and slow riffles in the main river to areas of intermittent flows in the Potlatch River to turbulent flow above and below falls in Elk Creek. Pools and slow riffles tended to be most typical of the habitat occupied. Ball (University of Idaho, now with Idaho Fish and Game, pers. comm.) reported that *Richardsonius* occurred at the headwaters of the North Fork Clearwater, but redside shiners were not taken in my collections from these areas.

Catostomus columbianus—Bridgelip Sucker.

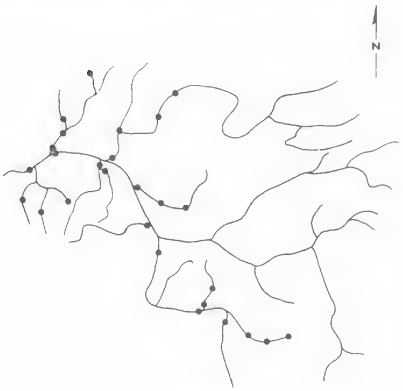
The bridgelip sucker is a species restricted to the Columbia and Fraser River systems (Carl *et al.,* 1967). This sucker is common in the Columbia system.

Catostomus columbianus was found from the headwaters of the South Fork Clearwater to the mouth of the main river, in the lower North Fork Clearwater, and in lowland tributaries (Fig. 13). The bridgelip sucker occurred at eight locations on

the South Fork Clearwater but did not occur in my collections from the Lochsa and the Selway systems.

Catostomus macrocheilus—Largescale Sucker.
The largescale sucker is a species native to the Pacific coast drainages from Sixes River, Oregon, north to the Nass River, and headwaters of the Peace River (Carl *et al*, 1967). This species was captured in two of my collections from the Clearwater (Fig. 14). Both of these collections were on the North Fork Clearwater, one above and one below the current location of Dworshak Dam. It is probable that largescale suckers are more widespread in the Clearwater than indicated by my collection.

Micropterus dolomieui—Smallmouth Bass.
The smallmouth bass is an introduced species which supports a fairly large sport



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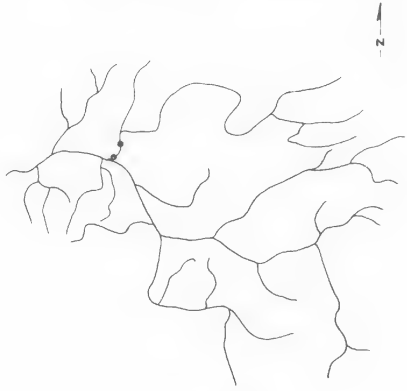

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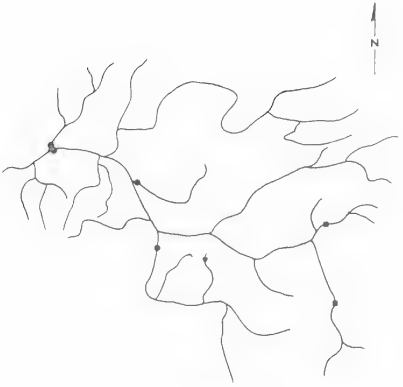

Figure 15.

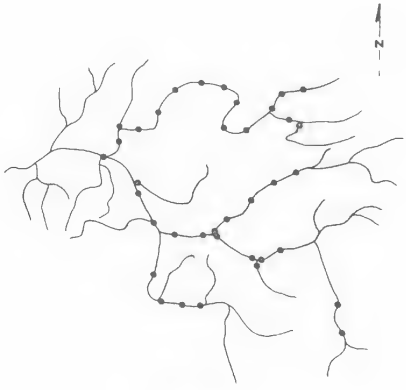

Figure 16.

Figure 13. Sites in the Clearwater drainage where bridgelip suckers were collected. Figure 14. Sites in the Clearwater drainage where largescale suckers were collected. Figure 15. Sites in the Clearwater drainage where smallmouth bass (●), Dolly Varden trout (▼), and chinook salmon (■) were collected or seen. Figure 16. Sites in the Clearwater drainage where mottled sculpins were collected.

fishery in the Columbia system. In my collections smallmouth bass were found only in the main Clearwater and the mouths of streams tributary to this area (Fig. 15).

Cottus bairdi—Mottled Sculpin.
Cottus bairdi is typically a species of cold, clear waters. This species is found in the upper Columbia, upper Missouri, and upper Colorado systems and in the east from Labrador to Alabama (Carl *et al.,* 1967). One particular morphological variant of this species was described as *Cottus hubbsi* (Bailey and Dimick, 1949). This form is the one found in the Clearwater.

Cottus bairdi was found throughout the main Clearwater and the major rivers (Fig. 16). The species was absent from the main Clearwater below the confluence of the North Fork Clearwater and tributaries (except perhaps at their mouths) to the major rivers.

Cottus beldingi—Piute Sculpin.
Cottus beldingi is a western species of the Lahonton, Bonneville, and Columbia drainages (Blair *et al.,* 1968). *Cottus beldingi* was found in the main Clearwater, major rivers, and tributaries entering the river below 3200 ft elevation (Fig. 17). Localized absences from the lower portion of the drainage were usually traceable to seasonal drying of the streams. *Cottus beldingi* was consistently absent from upstream portions of the tributaries entering the river above 3200 ft.

Cottus confusus—Shorthead Sculpin.
Cottus confusus is known from the Columbia and Puget Sound drainages. McAllister (1970) considered this species as rare and endangered in Canada as the result of large scale habitat destruction. In the U.S. the range is not completely known because of the recent description of the species (Bailey and Bond, 1963) and easy confusion with other forms.

Cottus confusus was taken from the headwaters of all major drainages above 3200 ft elevation (Fig. 18). Over most of the range this species was not found in cohabitation with the other cottids. Competitive exclusion may explain this phenomenon but data are lacking.

Cottus rhotheus—Torrent Sculpin.
Cottus rhotheus is a species of the Pacific Northwest. This species is found in the Columbia, Puget Sound, and Fraser River systems and is typically a stream species (Carl *et al.,* 1967).

Cottus rhotheus, like *Cottus bairdi,* was found throughout the main Clearwater and the major rivers (Fig. 19). This species is also absent from tributary streams (except perhaps at their mouths). *Cottus rhotheus,* unlike *Cottus bairdi,* is found from the mouth of the Clearwater upstream.

The interaction of cottids and other fishes in the Clearwater system is complex and not well understood. Cottids may be taken as food items by Dolly Varden and trout in the Clearwater system. They may also feed on salmon eggs and juveniles. Collectively, these species are the most abundant fishes in the system and one of the least known.

Biologists have long attempted to classify stream communities by fish species present.

MacPhee (1966) created the concept of the sculpin-trout biotope for the complex of species in the St. Joe River in northern Idaho to accomplish this end. My data indicate that the species of fishes in the Clearwater system can be loosely grouped into two subdivisions of the sculpin-trout biotope (Table 2). The first of these is the main river association. A subset of this association, including *Cottus beldingi, Lampetra tridentata, Rhinichthys osculus, Richardsonius balteatus,* and *Salmo gairdneri,* was found in the lowland tributaries. The second association found at the headwaters of major tributaries in the drainage consisted primarily of *Cottus confusus* and *Salmo clarki. Ascaphus truei* (tailed frogs) were also commonly taken with *Cottus confusus* and *Salmo clarki.*

Percopsis transmontanus—Sand Roller.

Pratt and Whitt (1952) and Simpson (1962) reported the sand roller from the lower Clearwater River. However, I failed to collect this species at any of my locations. It seems doubtful that this species now occurs widely or at high densities, considering the

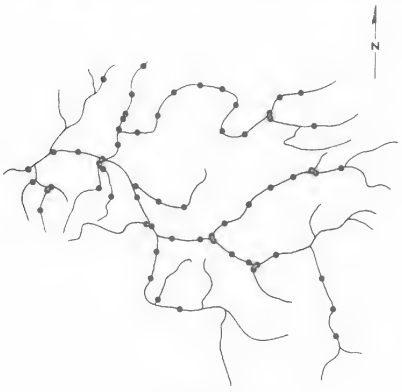

Figure 17.

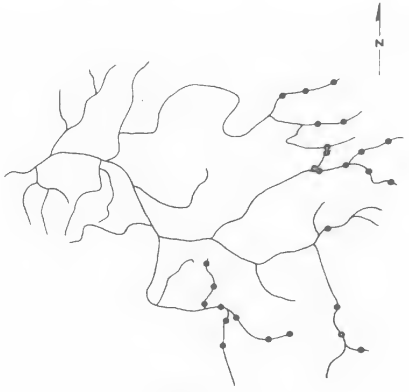

Figure 18.

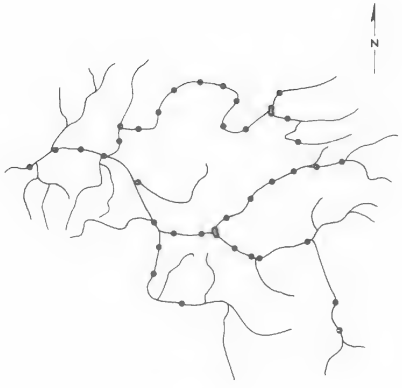

Figure 19.

Figure 17. Sites in the Clearwater drainage where piute sculpins were collected. Figure 18. Sites in the Clearwater drainage where shorthead sculpins were collected. Figure 19. Sites in the Clearwater drainage where torrent sculpins were collected.

TABLE 2. Species groups of Clearwater fishes excluding salmon.

Main River Species Group	Headwaters Species	Widespread Species
Cottus beldingi	*Cottus confusus*	*Salmo gairdneri*
Cottus rhotheus	*Salmo clarki*	*Catostomus columbianus*
Cottus bairdi	*Salvelinus malma*	*Prosopium williamsoni*
Lampetra tridentata		
Rhinichthys osculus		
Rhinichthys cataractae		
Richardsonius balteatus		
Ptychocheilus oregonensis		
Acrocheilus alutaceus		
Micropterus dolomieui		
Catostomus macrocheilus		

absence of this species from my collections. A special study might be warranted to determine the status of this species in the Clearwater.

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The Potential Effects of Urea Fertilization on *Peromyscus maniculatus* in Northwest Forests

Abstract

The potential for adverse effects of urea fertilizer on small forest mammals was investigated in the field and laboratory using the deer mouse, *Peromyscus maniculatus,* as a test animal. Acceptance of urea by small mammals was studied, disappearance rates of simulated applications of urea were examined under field conditions, and physiological effects of urea intoxication in *P. maniculatus* were observed. Results indicate that the application of urea as a forest fertilizer is not likely to damage populations of deer mice or other small mammals.

Introduction

Urea was first manufactured for use as a fertilizer in Germany about the time of World War I (Templeton, 1961). By 1925 urea was being used as an agricultural fertilizer in the United States (Hardesty, 1955). The high nitrogen content (46.7 percent) and water solubility of urea make it a desirable fertilizer. In recent years the Weyerhaeuser Company fertilized some of their more productive forest lands with urea to stimulate tree growth.

Urea is also used as a protein supplement in livestock grain rations. When ingested, urea is a metabolically active substance (Visek, 1962). In bovines, ingested urea goes through a series of reactions in the rumen which can provide valuable proteins and amino acids. In the ruminant, ingested urea is hydrolyzed by the bacterially produced enzyme urease to form two moles of ammonia from each mole of urea (Dintzis and Hastings, 1953). Other rumen micro-organisms can utilize this ammonia to form body proteins or amino acids of nutritional value to the ruminant (McLaren, 1964). Excess ammonia not utilized for protein or amino acid synthesis is absorbed by the portal blood and carried to the liver where it is reconverted to urea *via* the ornithine cycle (McLaren, 1964).

The feeding of urea to cattle is not hazardous to the animal if the urea content of the total grain ration does not exceed 3 percent (Osebold, 1947). Above this concentration urea can be toxic as a result of the rapid liberation of ammonia within the rumen and the inability of the liver to convert all of the excess ammonia to the non-toxic urea state. The ammonia that is not converted to urea in the liver is then carried throughout the body *via* the systemic blood, resulting in the disability or death of the animal.

The potential for ammonia intoxication resulting from urea ingestion is not restricted to ruminants. Urease, which is the only enzyme known to hydrolyze urea (Visek, 1962), is found in the gastro-intestinal tract of dogs and cats (Luck, 1924), rats and pigs (FitzGerald, 1946), and man (Glick, 1949). The presence of many urease producing bacteria in soils (Conrad, 1942) suggests that urease producing bacteria are present in the intestinal flora and gastric mucosa of small mammals that inhabit the forest.

Osebold (1947) and Dr. William Lawrence (pers. comm.) have recorded incidents of ruminants being attracted to and ingesting urea fertilizer. Dr. Lawrence reports an incident involving a sack of urea that was accidentally dropped from a truck during delivery. The truck crew failed to clean up the spilled urea and several dead cattle and deer were found in the vicinity of the spillage a few days later. Death was presumed to be caused by excessive urea ingestion.

Attraction to urea fertilizer, coupled with the potential for ammonia intoxication as a result of urea ingestion, served as the stimulus for this study. In this study, data were collected to provide information on the possible acute effects urea fertilization might have on *Peromyscus maniculatus,* and by inference, other small mammals in the forest. Field and laboratory studies, conducted from June through September 1974, examined attraction to and consumption of urea by *P. maniculatus.* Notes were taken on the physical responses exhibited by those animals known to have ingested urea. Also examined in the field was the rate at which solid urea dissipated under various circumstances of vegetation and weather.

Study Area

Four trapping programs and nine urea dissipation tests were conducted in the wooded area which comprises the southern part of The Evergreen State College campus, Thurston County, Washington. Locations of the first two trapping areas were 250 and 500 m east of Simmons Road, which forms the western boundary of the campus. The third and fourth field areas were established 100-200 m on either side of the north-south parkway that bisects the campus. The vegetation of this 41.25 ha area has been described by Acker *et al.* (1973). All areas selected for trapping programs and dissipation tests were situated under a canopy dominated by Douglas-fir, *Pseudotsuga menziesii.*

In an attempt to simulate the rate of urea dissipation on a clearcut area, four dissipation tests were conducted in a disturbed field located 200 m north of the campus core.

Methods

Field. Five trapping series, in the four forest areas, were conducted during the study. A different trapping plot was used for the initial four series. The fifth trapping series involved retrapping a plot using a bait combination not previously employed.

All trapping programs utilized forty-nine 7.6cm x 7.6cm x 22.8cm Sherman traps arranged along a 49-point grid. The grid was established with a Brunton compass and a 10-m tape measure. Upon locating an area in the forest that was dominated by *P. menziesii,* a point was selected arbitrarily and a trap was set. Six additional traps were placed at seven meter intervals north of this point. Six additional trap lines were set parallel to the first, at seven meter intervals.

In the initial trapping programs peanut butter and rolled oats, peanut butter laced with urea, and urea were used as bait in 25, 12, and 12 traps respectively. The fifth series tested peanut butter and rolled oats, urea, and no bait, in 25, 12, and 12 traps respectively. The order of treatment on the grid was decided before entering the field.

Trapping for each series was conducted over two to four day periods. Data collected for *P. maniculatus* captures included: 1) date, 2) toe clip code, 3) capture his-

tory, 4) trapping area, 5) trap site and bait used, and 6) a general description of the physical condition of the animal.

Success rates (captures/traps) were calculated on a daily basis for each bait. The Mann-Whitney non-parametric statistic (Zar, 1974) was applied to these values to examine similarities and differences in the success rates demonstrated by the various baits or no bait.

Observation. An observational test was conducted after each of the first four trapping programs was completed to examine attraction to and consumption of urea by *P. maniculatus.* Bait stations were established at those trap sites which exhibited the highest rate of success during a given trapping series.

Traps were removed from selected sites and a circular area with a diameter of approximately 20 cm was cleared of large twigs. To facilitate detection of tracks dry soil was sifted through a #40 sieve (opening 420 microns) and spread over the circle to a depth of 1 cm. Nine grams of urea were placed in the middle of the circle.

Concealed in nearby vegetation, I watched from dusk to approximately 2400 hours; some observations were conducted from 0430 to dawn. Data were collected on the duration and type (*i.e.,* visitation or feeding) of activity at the urea stations. As only one bait station could normally be observed on any given night all remaining bait stations were examined each morning for signs of visitation (*i.e.,* tracks around the urea) or feeding.

Eleven urea stations were established in the first three trapping areas and maintained for a total of 14 nights (40 bait nights). Urea was the only material presented at these stations. In addition to urea, peanut butter and rolled oats, and peanut butter laced with urea were used as potential attractants at the five bait stations established after completion of the fourth trapping program. Only one of the three bait combinations was used on any given night. The stations were maintained for a total of 19 nights, with the various attractants being employed in the following sequence: 1) urea, 3 nights; 2) peanut butter and oats, 9 nights; 3) urea, 4 nights; 4) peanut butter and urea, 3 nights. As a final test, duplicate plots were established adjacent to existing stations. Peanut butter laced with urea and urea only were used as baits on adjacent plots for three nights.

Rate of Dissipation. Two urea application rates were applied to dissipation plots. A rate of nine grams of urea per 929 cm^2 (1 sq ft) was applied to 26 forest plots and eight plots in the disturbed field. This rate is equivalent to an application of 400 lb of nitrogen per acre. At the present time urea is not being applied to the forest at this high rate. The second application rate, 3.3 g urea/929 cm^2, was applied to 13 forest plots and 8 plots in the disturbed field. This is equivalent to applying 150 lb N/acre; urea is presently being applied to the forest at this rate.

Plots were established by forming a 929 cm^2 area with twigs and spreading the quantity of urea throughout the square. Data on the density of the canopy and understory in the immediate vicinity of each plot were collected at this time. Daily checks were made at each plot until all of the urea had dissolved. Weather records from The Evergreen State College's weather station were used in data analysis.

Laboratory. A total of thirty-eight *P. maniculatus* were used in the laboratory. Twenty-

seven of these mice were trapped during a trapping series designed specifically to capture experimental animals. The 11 additional animals were progeny of three females pregnant at the time of capture.

Individuals were numbered as they were used in the experiments. A random number table was then used to assign individuals to one of four groups. The feeding group numbers and the urea: lab chow (Purina brand) feed ratios were as follows: 1) control (lab chow only), 2) 1 part urea: 3 parts lab chow, 3) 1 part urea: 1 part lab chow, 4) 3 parts urea: 1 part lab chow. The urea and lab chow were presented separately, allowing the animals to choose either when feeding. Forced feeding of urea was not attempted. Sunflower seeds, rolled oats, lettuce, or commercial wild bird seed were offered as supplements every other day.

During the second month of laboratory work urea was presented to the animals in their drinking water. Molar solutions of 0.0, 0.5, 0.75, and 1.0 were made available to feeding groups 1, 3, 4, and 2 respectively.

Initial data recorded on lab animals included: 1) date, 2) sex, 3) individual's number, 4) feeding ration assignment, and 5) weight. Measurements of food and water consumption and weight of individuals were recorded weekly. General notes on the behavior and physical condition of the animals were taken throughout the study.

Results

Field. Those traps which employed peanut butter as a portion of the bait showed the highest success rate in each of the first four trapping programs (Table 1). In all but the third trapping series, urea was the least successful bait used in the traps. Overall trapping success during the first four trapping programs was 14.9 percent for peanut butter and rolled oats, 15.2 percent for peanut butter and urea, and 3.8 percent for urea baited traps (Table 1).

In the fifth trapping series, traps containing urea had a 14.6 percent success rate, the highest value attained for traps containing urea in any of the five trapping programs. Only two *P. maniculatus* were captured in unbaited traps during the four night trapping period (Table 1).

Application of the Mann-Whitney statistic to the daily success rates produced the following conclusions: 1) individuals entered traps baited with peanut butter and urea or peanut butter and oats at comparable rates; 2) urea alone was less successful as a trap bait than peanut butter with rolled oats or with urea; and 3) there was no significant difference between the success rates of traps containing urea and those traps which were unbaited.

All *P. maniculatus* captured in traps baited with peanut butter and oats were vigorous at the time of release. *P. maniculatus* mortality was 100 percent (5 animals) in traps containing urea only during the first four trapping programs and 57.1 percent (4 animals) during the fifth trapping series. Of the two individuals captured in unbaited traps one died. Fifteen percent of the individuals (3 animals) that entered peanut butter and urea baited traps were dead when traps were checked. An additional 25 percent of the individuals (5 animals) captured in these traps were in poor physical condition, and were not retrapped.

The movements of those individuals in poor physical condition were slow and erratic. The eyes were half closed and poor balance and coordination were evident.

TABLE 1. Trapping Data

Series	Nights Trapped	Peanut Butter and Oats			Peanut Butter and Urea			Urea		
		Success	Mortality	Loss of Vigor	Success	Mortality	Loss of Vigor	Success	Mortality	Loss of Vigor
1	2	18%	0%	0%	33.3%	25%	50%	0%	0%	—
2	3	13.3	0	0	5.5	0	0	2.8	100	—
3	3	2.7	0	0	8.3	0	33.3	5.6	100	—
4	3	26.7	0	0	19.9	0	14.6	5.6	100	—
Total	11	14.9%	0%	0%	15.2%	15%	25%	3.8%	100%	—

Series	Nights Trapped	Peanut Butter and Oats			Urea			No Bait		
		Success	Mortality	Loss of Vigor	Success	Mortality	Loss of Vigor	Success	Mortality	Loss of Vigor
5	4	36%	0%	0%	14.6%	57.1%	14.2%	4.3%	50%	0%

Success=no. of captures/trap nights for the given bait x 100
Mortality=no. of dead animals/captures of the given bait x 100
Loss of Vigor=no. of animals in poor physical condition/captures of the given bait x 100

Attempts at grooming were frequent but generally unsuccessful. Convulsions were experienced during three to five minute intervals of inactivity. All animals in this condition were easily recaptured by hand.

Bait Stations. At the eleven bait stations established in the first three trapping areas no sign of urea consumption was recorded during the 14-day observation period. Visits to these sites by small mammals were recorded five times.

In the fourth trapping area, stations baited with urea were visited every night. Scattering of urea occurred at all five sites the first night urea was made available. On subsequent nights only one additional incident of urea scattering was recorded and no animal was seen eating urea. Peanut butter and oats, and peanut butter laced with urea, were consumed every night when available at the stations. When peanut butter laced with urea and urea only were used as baits at adjacent stations, the peanut butter and urea were eaten every night, but the urea was never taken.

Rate of Dissipation. Dissipation test plots in the forest were under a closed canopy of *P. menziesii.* Very low densities of salal, *Gaultheria shallon,* and Oregon grape, *Berberis nervosa,* were characteristic of the understory vegetation at these sites. Grasses and annuals were the dominant vegetation forms at test sites in the disturbed field.

The data from these tests show that the rate of urea dissipation was dependent upon: 1) rain; 2) the application rate of urea; 3) soil moisture at the time of application; and 4) the density of vegetation at the application site.

Nine grams of urea were placed on all plots for the first four tests. No rainfall during the first test resulted in an average dissipation rate of 69 hr (Table 2). Rain was recorded during the 2nd, 3rd, and 4th tests. Urea dissipated more rapidly during the 2nd test (39.5 hr) because rain fell from the 20th through the 33rd hr of the test (Table 2). More time was required to dissolve urea during the 3rd (62 hr) and 4th (58 hr) tests because rain did not fall until the 50th hr of the 3rd test and the 48th hr of the 4th test (Table 2).

Nine grams or 3.3 g of urea were applied to adjacent forest plots for tests 5-9. When applied at a rate of 3.3 g/929 cm^2 urea dissolved more rapidly in all tests (Table 2). The average dissipation rate on 9 g plots was 6 to 40 hr longer than at 3.3 g plots (Table 2).

In the absence of rain, the time required to dissipate urea from the plots of the 5th, 8th, and 9th tests varied considerably. Differences in soil moisture at the time of urea application caused this variation. When plots were established for test eight the soil was moist; urea dissolved from these plots in 24-48 hr (Table 2). The soil was dry when test five was initiated; dissipation took 48-88 hr (Table 2).

The rate at which urea dissipated from plots in the disturbed field was very dependent on precipitation. Urea remained visible 14 days after it was applied at both application rates (test 12, Table 2). Rain on day 14 immediately dissolved all remaining urea. Moist soil conditions prevailed when plots were established for the 11th test and 0.8 mm of rain was recorded during the first 6 hr of this test. All urea dissipated within 18 hours.

When wet conditions prevailed, urea dissolved more readily at plots in the disturbed field; in the absence of rain urea dissipated faster at forest plots. Differences in the vegetation density in these two areas account for the variation in the rate of urea dissipation. Sparse vegetation in the disturbed field resulted in less interception of rain,

TABLE 2. Dissipation Tests

Test	Field Area	9 g of urea per 929 cm²		3.3 g of ureau per 929 cm²		Measurable Rain (mm) During Test	Rain (Hrs. after Urea Application)
		No. of Plots	Diss. Rate (hrs) Ave. (Range)	No. of Plots	Diss. Rate (hrs) Ave. (Range)		
1	1	3	69 (61-85)			0	—
2	2	4	39.5 (36-60)			0.8	20th-33rd
3	3	3	62 (46-70)			1.0	50th-60th
4	4	3	58 (50-70)			19.3	48th-72nd
5	4	3	88 (48-144)	3	48 (48)	0	—
6	4	2	68 (68)	2	56 (48-60)	3.3	60th-68th
7	4	2	24 (18-30)	2	18 (18)	0.8	0-3rd
8	4	2	48 (48)	2	24 (24)	0	—
9	4	4	54 (48-72)	4	36 (24-48)	0	—
10	5	2	68 (68)	2	68 (68)	3.3	60th-68th
11	5	2	18 (18)	2	18 (18)	0.8	0-3rd
12	5	2	14 days	2	14 days	4.8	14th day
13	5	2	12 days	2	12 days	4.8	12th day

hence, more rapid urea dissipation during periods of rain. Under dry conditions urea dissipated quicker in the forest because the exposed soil in the disturbed field dried out faster and dew formation in the forest was greater.

Laboratory. Urea was not readily accepted as food by laboratory animals. Only one case of direct voluntary urea consumption was recorded during laboratory studies. The female involved in this incident consumed 3.5 g of urea within a 24-hr period. This animal exhibited the symptoms of intoxication that were described earlier for field animals that were in poor physical condition at the time of release (*i.e.,* loss of equilibrium, spasms, etc.). In an attempt to restore the vigor of this individual, fresh lettuce was offered. The roughage was readily accepted and within 24 hr the symptoms were gone.

No change in the physical condition of any animals in the control or 0.5M water groups was recorded. Four of the nine individuals of the 0.75M group and six of the ten animals of the 1.0M group displayed symptoms of intoxication. Intoxicated animals (two from the 0.75M group, and three from the 1.0M group) recovered after they were given untreated water and roughage (lettuce) for one night. The other two and three animals, left on dosage, died.

After recovery, treated animals were again offered urea water. Symptoms recurred in one of five cases. This individual was given the recovery treatment a second time and vigor was once again restored. A third administration of urea water to this individual produced no symptoms of intoxication.

Application of the Mann-Whitney statistic to the water consumption rates of individuals from each of the four water groups showed that consumption by animals in the 0.5M group and unaffected individuals of the 0.75M and 1.0M groups did not differ significantly from the consumption rate of controls. Animals that were adversely affected consumed more water per day than did controls.

A reduction of food consumption by those individuals that died or were affected was shown when food data were analyzed with the Mann-Whitney test. All other animals consumed food at comparable rates.

Weight reductions of 1.5 to 6 g were evident in all sick or dead animals except in the case of two juveniles. These animals continued to gain weight throughout the period of stress. Weight fluctuations were common among animals in all feeding and watering groups studied.

Discussion and Summary

During this study adverse effects from urea ingestion did result when urea, in traps or in drinking water, was presented to the animals as the only ingestible alternative. In natural field situations alternate food and water sources would be available at all times. The molarity of urea water causing toxicity (0.75 M and 1.0M) is considered higher than levels that would occur in the field as a result of a fertilization program.

Visek (1968) has described the primary observable signs of acute ammonia poisoning to be neurological and reversible without evidence of structural damage. In this study complete recovery was recorded in all cases when animals were treated for urea (ammonia) intoxication.

Urea is less toxic when starch is present in the diet (Visek, 1968). Large quantities of starch, in the form of seeds and fruits, are an integral part of the diet of *P. mani-*

culatus (Baker, 1968). The ingestion of starch through the normal feeding habits of *P. maniculatus* would therefore reduce the risk of urea intoxication in the field.

Another factor reducing the potential of urea intoxication, as a result of the direct consumption of urea applied as a forest fertilizer, is the rapid dissipation rate of urea when applied under wet conditions. At the present time urea is applied to the forest in the fall: by mid-April the application programs are completed (Borrecco, pers. comm.). In Western Washington moist conditions prevail during this time period. Therefore, if the application of urea, at the present rate of 150 lb of nitrogen per acre, is synchronized with the occurrence of rain during this time of year, solid urea will remain available as a food source for 10-18 hr in clear cut areas and 18-36 hr in the forest. A higher application rate of 400 lb N/acre will increase the time required to dissipate urea in the forest. At this application rate and under wet conditions urea will dissipate in 24-40 hr in the forest. In clear cut areas urea will dissipate at approximately the same rate for either application rate if rain falls after the urea has been applied.

Data from field trappings, bait station maintenance, and the laboratory feeding program indicate that *P. maniculatus* will not accept urea as food under natural conditions. As a trap bait, urea was statistically less effective than peanut butter and oats, or peanut butter laced with urea; daily capture rates for unbaited traps were comparable to the rates for traps containing urea. Individuals captured in traps containing urea probably entered those traps for reasons other than attraction to urea. When urea was made available at bait stations *P. maniculatus* visited the sites, but did not accept urea as food. Laboratory animals, given urea and lab chow as separate food sources, consistently preferred the lab chow. During the two-month feeding program only one incident of urea intoxication, as a result of direct consumption, was recorded.

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Mountain Caribou: Threats to Survival in the Kootenay Pass Region, British Columbia

Abstract

The Kootenay Pass region of southeastern British Columbia represents a vital segment of habitat for mountain caribou inhabiting the Selkirk Mountains. Existing and proposed developments there, including a major highway, power transmission lines, a natural gas pipeline and extensive logging, have reduced available habitat, modified caribou movements and intensified man-caused harassment and mortality. Continuing human encroachment jeopardizes the future existence of mountain caribou in the Kootenay Pass region.

Introduction

Mountain caribou, *Rangifer tarandus montanus* (Seton), ranged throughout the Selkirk Mountains of British Columbia, Idaho, and Washington during historic time (Freddy, 1974; Layser, 1974). There is evidence that the Kootenay Pass region in southeastern British Columbia has represented a vital segment of habitat for these caribou for more than a century. A detachment of the Palliser Expedition led by John W. Sullivan crossed the Selkirk Range in September, 1859, essentially following the present route of B. C. Highway 3 up Stagleap Creek, across Kootenay Pass (1,775 m or 5,820 ft) and down Summit Creek. In his report Sullivan stated:

> At the height of land I was in hopes that we had struck an Indian trail, when suddenly our guide informed me that we had been traveling for the last half hour, not upon an Indian, but a carriboeuf road, and that now we were forced to leave it. Carriboeufs frequent this part of the country in large numbers, as the woods are traversed by their beaten tracks (Spry, 1968:482).

A recent investigation (Freddy, 1974) and those in progress (Johnson, Miller, and Money, unpubl.) confirm the continued and intense use of the Kootenay Pass region by the Selkirk band of caribou throughout the year. Kootenay Pass serves as the movement corridor for caribou that enter the United States (Freddy, 1974:83). The existing undisturbed parts of the region are considered absolutely vital for the survival of this band. Hence, a review is in order so that the public, the scientific community, and the resource agencies can be fully informed of the existing and proposed developments at Kootenay Pass which threaten this band.

Highway Development

The completion of B. C. Highway 3 in 1963 initiated development in the region (Fig. 1). The "Kootenay Skyway" is maintained as an all-weather highway. This route is particularly attractive to trans-Canada travelers since it avoids time-consuming and more hazardous northern routes.

The use of salt in winter road maintenance has attracted caribou to the highway where a single collision with a motor vehicle might kill or injure several animals. On 2 December 1974, for example, eight animals visited the highway and six were photo-

graphed on the pavement licking salt (John Russell, pers. comm.). The threat of mass slaughter in a collision, especially on icy winter roads, is self-evident. At least five caribou have been killed in collisions with vehicles thus far (Layser, 1974).

Assessing the influence of the highway on caribou movements is difficult. Klein (1971) has reported the reluctance of wild reindeer to cross a main highway and railroad in Norway. Impedence of movement in the Kootenay Pass region would seem to be greatest during late winter when snow is steeply banked along the roadside. Total snowfall has averaged 15 m during the past ten winters (Table 1). Although caribou

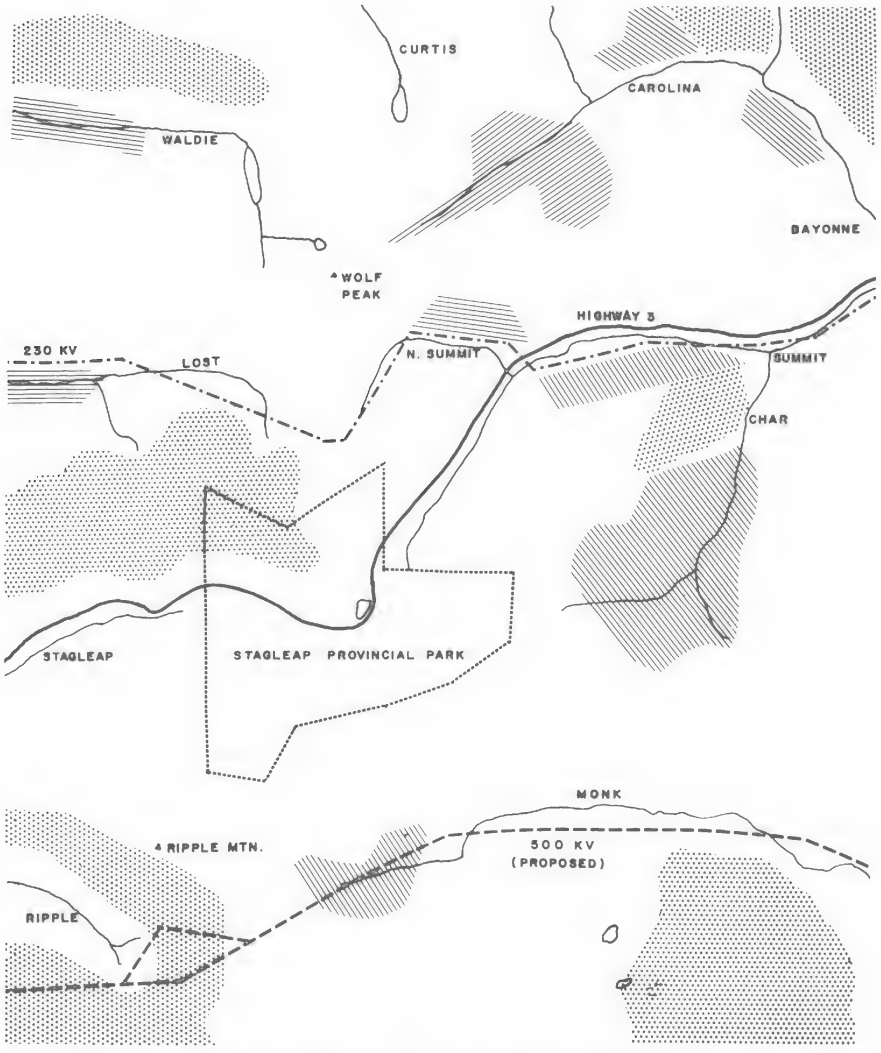

Figure 1. Kootenay Pass Region, British Columbia. Existing B. C. Highway 3-solid line; existing power transmission and natural gas pipeline- dot-dash line; authorized power transmission line, proposed route- dashed line; clearcuts- hatched; burns- stipled. International boundary at bottom of the figure. Scale: 1 in = 1.3 mi.

have crossed the highway in December, March, and April (Freddy, 1974), there is no evidence that the highway has modified caribou movement during the winter months. The highway provides ready access for illegal hunting (Freddy, 1974). This band has not been hunted legally since 1957 (Flinn, 1956:38).

TABLE 1. Total snowfall (m), Kootenay Pass, B. C. (H. Kelsall, pers. comm.)

Winter	Snowfall
1965-66	14.1
1966-67	16.1
1967-68	14.4
1968-69	15.4
1969-70	10.2
1970-71	21.2
1971-72	16.3
1972-73	11.6
1973-74	19.0
1974-75	12.7
Mean	15.1

Utility Development

The establishment of the highway has made the Kootenay Pass region attractive as a utility corridor. A 230 kv power line has been installed through the Lost Creek and North Summit basins (Fig. 1). Old-growth Engelmann spruce, *Picea engelmanni,* and subalpine fir, *Abies lasiocarpa,* were cleared for right-of-way through these basins, reducing the availability of arboreal lichens, the primary winter food of mountain caribou (Edwards and Ritcey, 1960).

The effect of power transmission lines on caribou movement has not been assessed. There is no evidence at the present time to indicate that the power line has affected caribou movements in the Kootenay Pass region. A greater threat probably results from the improved access provided by rights-of-way for off-the-road-vehicles during summer and for snowmobiles during winter.

The route of the 500 kv power line connecting Nicola and Cranbrook through the region is currently under study (Ian Hayward, pers. comm.). Present plans favor a 200-ft right-of-way through the Ripple and Monk Creek basins, utilizing as much of the existing clearcut as is feasible (Fig. 1). In crossing the Ripple-Monk summit the line would be split to reduce the chances that an avalanche or landslide will disrupt power transmission through this rugged region. Some loss of old-growth timber will occur in the upper reaches of Monk Creek depending upon the route chosen and the spacing of towers. A second 500 kv line, which will likely parallel the one currently authorized, is also under consideration.

The microwave relay station on the summit west of Kootenay Pass has had a minimal impact on this band and their habitat although its service road provides access to the upper parts of Lost Creek.

Construction began on a 12-inch natural gas pipeline in 1975 which will parallel the existing power line through much of the North Summit and Lost Creek drainages. A divergence of its right-of-way in the North Summit basin caused some loss of old growth timber.

Fire and Logging

Edwards (1954) has described the detrimental effects of forest fires on a mountain caribou herd in Wells Gray Provincial Park, B. C. Forest fires have devastated a large part of the Kootenay Pass region (Fig. 1). In 1920 a fire burned much of the area south of Ripple Mountain and in the Stagleap and Lost Creek basins. A lightning-caused fire destroyed a large part of the timber in the Waldie Creek basin in 1945 (D. E. Gilbert, pers. comm.). An early forest fire burned over the ridge separating Bayonne and Carolina Creeks (Fig. 1). Unfortunately, several hundred acres of second growth forest on this site were burned in October, 1974, when a fire escaped the Carolina Creek clearcut. In a similar manner, mature timber in the Char Creek basin was destroyed in 1967 when a clearcut burn escaped into green timber.

Much of the old-growth spruce and subalpine fir have been removed from the Monk Creek basin where logging began in 1954 and from the Caroline Creek basin were logging commenced in 1967. Both areas are historically and currently important to caribou. Large amounts of mature timber have also been removed from the Char, Summit, Maryland, and Lost Creek basins (Fig. 1). Much of this timber was 100-150 years old. Recovery will only take place slowly, particularly at higher elevations. The remaining timber appears to be absolutely essential as a source of winter food and cover for this band of caribou. Fortunately, the British Columbia Forest Service has adopted a policy to limit further timber removal in these basins.

Discussion

Development of the Kootenay Pass region has proceeded rapidly during the past three decades to the point where the resident band of caribou may soon be seriously threatened both from habitat loss and from direct man-caused mortality. The band currently numbers 25-30 individuals. The calf crop has not exceeded five animals during each of the past four years. Confirmed mortality has equalled recruitment in two and perhaps in three of these years (Freddy, 1974, and unpublished data). Although these caribou represent a minor part of the total caribou population of British Columbia, elements of the herd cross the International Border and thus become a part of the last remnant of caribou in the contiguous United States. For that reason alone their survival assumes a special significance.

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Food Habits of Five Western Oregon Shrews[2]

Abstract

The five most important foods, by decreasing percentage volume, among 158 Trowbridge shrews, *Sorex trowbridgii,* were centipedes, spiders, internal organs of larval invertebrates (probably mostly beetles), slugs and snails, and unidentified invertebrates. Among 30 vagrant shrews, *S. vagrans,* the five most important foods were insect larvae, slugs and snails, unidentified invertebrates, *Endogone,* and spiders. In 30 Pacific shrews, *S. pacificus,* the five most important foods were slugs and snails, centipedes, amphibian flesh, insect larvae, and unidentified invertebrates. In 27 Yaquina shrews, *S. yaquinae,* the five most important foods were invertebrate internal organs, unidentified insect larvae, slugs and snails, coleopterous larvae, and unidentified invertebrates. Among 24 marsh shrews, *S. bendirii,* the foods were insect larvae, slugs and snails, Ephemeroptera naiads, unidentified invertebrates, and earthworms.

There is little information on the food habits of western shrews despite the following studies: (1) Trowbridge shrew—Jameson (1955); (2) Vagrant shrew—Broadbooks (1939), Eisenberg (1964), Maser (1966); (3) Pacific shrew—Maser and Hooven (1974); and (4) Marsh shrew—Langeman (1947), Pattie (1969). These studies focused primarily on captive individuals. The purpose of this paper is to present information on the food habits of wild shrews in western Oregon. Because of unresolved taxonomic problems with shrews of the genus *Sorex* in the Pacific Northwest, we are following the recommendations of Johnson and Ostenson (1959) with respect to their nomenclature.

Methods and Materials

The shrews were trapped over a period of three years; most were caught in unbaited snap traps. Many of the snap-trapped shrews had empty stomachs and most of the live-trapped shrews had stomach contents which were contaminated with trap bait, accounting for the small sample size of four of the five species studied. Stomach contents were preserved in 10 percent formalin. Reference materials were also collected in the field for comparative purposes. Stomach contents were identified and the volume percentages of each food in each stomach were visually estimated using a 10 to 70 power zoom dissecting microscope.

Description of Study Area

Most of the shrews in this study were captured along the Oregon coast from the Cascade Head Experimental Forest, near Otis, Lincoln County, southward to the California border.

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[2] The present paper is a contribution of the Oregon Coast Ecological Survey, Puget Sound Museum of Natural History, University of Puget Sound, Tacoma, Washington, and contribution 192 of the Coniferous Forest Biome, U.S. Analysis of Ecosystems, International Biological Program.

A few were caught in the H. J. Andrews Experimental Forest, Lane County, which lies on the western flank of the Cascade Mountain Range.

The shrews along the coast were taken in the Sitka spruce, *Picea sitchensis,* zone of Franklin and Dyrness (1973) whereas those taken on the western flank of the Cascades were taken in the western hemlock, *Tsuga heterophylla,* zone.

Results and Discussion

The results of the food-habit analysis are given in Table 1.

TABLE 1. Foods eaten by five species of shrews of the genus *Sorex* from Oregon.

Food Items	*S. trowbridgii* Vol.	Freq.	*S. vagrans* Vol.	Freq.	*S. pacificus* Vol.	Freq.	*S. yaquinae* Vol.	Freq.	*S. bendirii* Vol.	Freq.
Chilopoda	15.4	33.5	0.6	6.7	10.7	50.0	0.2	3.7	1.7	8.3
Spider	11.6	24.7	4.7	13.3	0.8	6.7	4.6	18.5	6.3	16.7
Invertebrate internal organs	10.5	18.4	0.5	3.3	0.8	3.3	28.6	37.0	---- --	---- --
Slugs and snails	9.4	17.1	14.0	30.0	28.0	46.7	7.0	11.1	14.9	37.5
Unidentified invertebrate	8.1	34.2	13.8	40.0	6.1	23.3	5.2	18.5	12.3	45.8
Unidentified insect larvae	3.7	8.2	17.8	23.3	8.7	26.7	7.9	18.5	16.3	29.2
Hemiptera	3.6	9.5	0.8	6.7	0.9	10.0	1.1	3.7	---- --	---- --
Phalangida	3.3	9.5	0.5	3.3	3.2	10.0	---- --	---- --	1.7	12.5
Coleoptera	3.3	13.3	4.2	16.7	0.7	3.3	0.9	7.4	1.0	12.5
Dipterus larvae	2.7	5.7	3.2	10.0	2.8	10.0	5.0	11.1	---- --	---- --
Vegetation	2.0	9.5	2.3	3.3	0.8	6.7	2.4	3.7	0.2	4.2
Diptera	2.0	10.8	0.7	3.3	0.7	6.7	0.4	3.7	0.6	8.3
Lygaeidae	1.8	7.0	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Earthworms	1.7	6.3	3.8	13.3	1.8	6.7	0.2	3.7	7.9	8.3
Coleopterous larvae	1.7	9.5	4.3	10.0	3.3	10.0	5.4	7.4	0.6	8.3
Scarabaeidae	1.6	3.8	4.0	6.7	0.5	3.3	0.6	3.7	---- --	---- --
Cicadellidae	1.4	3.2	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Unidentified material	1.4	2.5	---- --	---- --	3.3	3.3	5.0	3.7	---- --	---- --
Lepidoptera	1.3	2.5	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Lepidopterous larvae	1.3	2.5	2.0	3.3	---- --	---- --	1.9	7.4	---- --	---- --
Hymenoptera	1.3	5.1	0.7	3.3	---- --	---- --	3.7	14.8	0.2	4.2
Sowbug	1.3	4.4	---- --	---- --	---- --	---- --	0.6	7.4	---- --	---- --
Tipulidae	1.2	1.9	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Endogone	1.2	5.1	6.7	4.0	2.2	10.0	1.5	7.4	0.6	4.2
Gryllidae	0.9	4.4	---- --	---- --	1.8	10.0	---- --	---- --	---- --	---- --
Ichneumonidae	0.9	3.2	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Pentatomidae	0.9	1.3	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Mast	0.6	0.6	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Cerastium-flowers & seeds	0.6	0.6	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Tenebrionidae	0.6	0.6	---- --	---- --	---- --	---- --	1.3	3.7	---- --	---- --
Moss	0.4	1.9	---- --	---- --	0.8	3.3	---- --	---- --	---- --	---- --
Formicidae	0.4	2.5	1.8	3.3	---- --	---- --	0.4	3.7	0.6	4.2
Collembola	0.4	2.5	0.5	3.3	---- --	---- --	---- --	---- --	0.2	4.2
Carabidae	0.3	1.3	3.3	3.3	1.5	6.7	1.5	3.7	1.0	4.2

Curculionidae	0.3	1.9	3.5	6.7	1.5	10.0	1.7	3.7	---- --	---- --
Lycidae	0.2	1.3	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Tipulid larvae	0.2	0.6	---- --	---- --	3.2	6.7	3.7	3.7	4.2	8.3
Pseudoscorpions	0.1	0.6	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Sarcophagidae	0.1	0.6	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Scarabaeid larvae	0.1	0.6	0.5	3.3	---- --	---- --	3.1	3.7	---- --	---- --
Phoridae	0.1	0.6	0.5	3.3	---- --	---- --	---- --	---- --	---- --	---- --
Tingidae	0.1	1.9	---- -	---- --	---- --	---- -	---- --	---- --	---- --	---- --
Termites	0.1	0.6	---- --	---- --	---- --	- - --	---- --	---- --	---- --	---- --
Elaterid larvae	0.1	0.6	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Sciaridae	0.1	0.6	---- --	---- --	- - --	---- -	---- --	---- --	---- --	---- --
Carabid larvae	0.1	0.6	---- --	---- --	---- --	---- --	1.1	3.7	---- --	---- --
Myctetophilidae	trace	0.6	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --
Homoptera	---- --	---- --	2.4	13.3	---- --	---- --	---- --	---- --	---- --	---- --
Chauliognathus larvae	---- --	---- --	1.0	6.7	---- --	---- --	---- --	---- --	---- --	---- --
Aphididae	---- --	---- --	0.8	6.7	---- --	---- --	---- --	---- --	---- --	---- --
Syrphidae	---- -	---- --	0.7	6.7	---- --	---- --	---- --	---- --	---- --	---- --
Reduviidae	---- --	---- --	0.5	3.3	---- --	---- --	---- --	---- --	---- --	---- --
Amphibian flesh	---- --	---- --	---- --	---- --	6.1	13.3	---- --	---- --	---- --	---- --
Seeds	---- --	---- --	---- --	---- --	3.3	3.3	---- --	---- --	---- --	---- --
Diplopoda	---- --	---- --	2.7	3.3	2.7	6.7	---- --	---- --	---- --	---- --
Insect eggs	---- --	---- --	---- --	---- --	1.8	3.3	---- --	---- --	---- --	---- --
Fungi	---- --	---- --	---- --	---- --	1.5	6.7	---- --	---- --	---- --	---- --
Ant eggs	-- ----	---- --	---- --	---- --	0.2	6.7	---- --	---- --	---- --	---- --
Tick	---- --	---- --	---- --	---- --	trace	3.3	---- --	---- --	---- --	---- --
Flesh	---- --	---- --	---- --	---- --	---- --	---- --	3.9	7.4	---- --	-- - --
Staphylinid larvae	---- --	---- --	---- --	---- --	---- --	---- --	0.6	3.7	---- --	---- -
Cydnidae	---- --	---- --	---- --	-- - --	---- --	---- --	0.6	3.7	- --	---- --
Hemerobiidae	---- --	---- --	---- --	--- -	---- --	---- --	0.2	3.7	---- --	---- --
Ephemeroptera naiads	---- --	---- --	---- --	---- -	---- --	---- --	---- --	---- --	12.6	29.2
Bittacomorpha clavipes	---- --	- -- --	---- --	---- --	---- --	---- --	---- --	---- --	4.2	8.3
Stratiomyid larvae	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --	4.2	4.2
Tettigoniidae	---- --	---- --	- - - -	---- --	---- --	---- --	---- --	---- --	4.2	4.2
Plecoptera naiads	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --	1.5	8.3
Sialidae larvae	---- --	---- -	- -- --	-- - --	---- --	---- --	---- --	---- --	1.5	8.3
Gerridae	- - --	---- --	---- --	---- -	---- --	---- --	---- --	---- --	0.6	4.2
Asilidae	---- -	---- --	---- --	---- --	---- --	---- --	---- --	---- --	0.6	4.2
Chironomid larvae	---- --	---- --	---- --	---- --	---- --	---- --	---- --	---- --	0.4	8.3
TOTAL	100.4		100.1		99.7		100.3		100.1	

Specific habitat and food considerations.

Sorex trowbridgii, Trowbridge shrew: Trowbridge shrews are strictly nocturnal. They are the most common and adaptable species of western forest shrews. Occurring in all forest habitats, they are most abundant around and under logs in the Alder/Salmonberry community (Maser and Franklin, 1974). The five major foods were centipedes, spiders, internal organs of invertebrates (probably mostly beetles), slugs and snails, and un-

identified invertebrate materials. Forty-seven types of foods were eaten. Total volumes of adults of some of the predominant orders of insects were Coleoptera 6.5 percent, Hemiptera 6.3 percent, Diptera 3.5 percent, Hymenoptera 2.6 percent. Insect larvae, collectively comprised 9.9 percent of the volume although lepidopterous larvae, often a common insectivore dietary item, comprised only 1.3 percent. Higher vegetation made up only 3.2 percent of the volume, whereas the subterranean fungus, *Endogone,* often common as a shrew food (particularly *Blarina*) in the eastern United States, made up only 1.2 percent

Sorex vagrans, Vagrant shrew: Vagrant shrews are active throughout the 24-hr cycle. They are inhabitants of coastal prairies, meadows, fields, and grassy areas adjacent to streams; they also occur in the deflation plains of the costal sand dunes. (For a discussion of sand-dune anatomy refer to Wiedemann *et al.,* 1969.) These small shrews are most abundant and spend most of their time in the runways of voles, *Microtus.* Insect larvae, slugs and snails, unidentified invertebrates, *Endogone,* and spiders were the five major foods; a total of 30 categories of foods were identified. Total volumes of some of the major orders of insects were Coleoptera 15.0 percent, Hemiptera 1.3 percent, Diptera 1.9 percent, and Hymenoptera 2.5 percent.

Sorex pacificus, Pacific shrew: Pacific shrews are nocturnal; they are the second largest of the western Oregon shrews. In Oregon, Pacific shrews are confined to the southwestern corner of the state from the general vicinity of Gardiner, Lane County, southward into northwestern California. They are primarily inhabitants of the Riparian Alder/Small Stream and Skunkcabbage Marsh habitats (as defined by Maser and Franklin, 1974) of the flat, coastal, marine terraces. Most abundant around and under ground cover, they burrow extensively where such cover is absent. The five major foods of Pacific shrews were slugs and snails, centipedes, amphibian flesh, unidentified insect larvae, and unidentified invertebrates. Twenty-nine types of foods were eaten by these large shrews. Total volumes of adults of some of the major orders of insects were Coleoptera 4.2 percent, Hemiptera 0.9 percent, Diptera 0.7 percent, Hymenoptera 0 percent. Larval insects, collectively, made up 18.0 percent of this sample. Vegetative matter made up 4.1 percent of the volume, primarily as a result of the occurrence of seeds filling the stomach of one individual. Fungal foods formed 3.7 percent of the total volume.

Sorex yaquinae, Yaquina shrew: these medium-sized nocturnal shrews occur along the coast from the vicinity of Oceanlake, Lincoln County, southward to the vicinity of the Siltcoos River and Siltcoos Lake, Lane County, and eastward into the H. J. Andrews Experimental Forest. Although forest-dwellers, Yaquina shrews along the coast are primarily inhabitants of the Alder/Salmonberry, Riparian Alder, and Skunkcabbage Marsh habitats (Maser and Franklin, 1974). Invertebrate internal organs were the top food in this species, approaching one-third of the diet. The other four top foods consisted of unidentified insect larvae, slugs and snails, coleopterous larvae, and unidentified invertebrates. Diversity of food items included 30 categories. Total volumes of adults of some of the major orders of insects were Coleoptera 6.0 percent, Hemiptera 1.7 percent, Diptera 0.4 percent, and Hymenoptera 4.1 percent. Vegetation formed 2.4 percent of the material, while the fungus *Endogone* made up 1.5 percent.

Sorex Bendirii, Marsh shrew: the Marsh shrew is the largest species within the genus *Sorex* and is the most aquatically oriented species in western Oregon. Operating

throughout the 24-hr cycle, marsh shrews are largely constrained to the Skunkcabbage Marsh and Riparian Alder/Small Stream habitats throughout most of the year (Maser and Franklin, 1974). A total of twenty-six types of foods composed the diet of the marsh shrew, including nine types of food not found in the other species examined. At least 25 percent of the material found in stomachs was aquatic, and probably some of the material listed as slugs and snails, unidentified invertebrates, and unidentified insect larvae was also aquatic. The top foods in this species were unidentified insect larvae, slugs and snails, Ephemeroptera naiads, unidentified invertebrates, and earthworms. Total volumes of some of the major orders of insects were Coleoptera 2.0 percent, Hemiptera 2.6 percent, Diptera 1.2 percent, and Hymenoptera 0.8 percent. Vegetation formed only 0.2 percent of the food, and fungus 0.6 percent.

Comparative habitat and food considerations.

The five species of shrews along the Oregon coast can be separated into four basic habitat orientations, related to successional stage vegetation. The marsh shrew is the most specialized in habitat requirements; its orientation is primarily aquatic. The Pacific and Yaquina shrews are both forest-dwellers, but their basic orientation is toward marshy areas and the moist banks of small, relatively slow-flowing streams. The vagrant shrew is the only western Oregon shrew with a truly grass-meadow orientation. Only the Trowbridge shrew is adaptable enough to populate climax forest communities thoroughly. Although its basic orientation is toward the coniferous forest in general, in extreme southwestern Oregon it occurs in the tanoak, *Lithocarpus densiflorus*/madrone, *Arbutus menziesii,* forest.

Of the five species of shrews examined, the most common food was insect larvae in *Sorex vagrans* and *S. Bendirii* (different types of larvae were probably involved); slugs and snails, primarily *Haplotrema vancouverense,* in *S. pacificus;* centipedes in *S. trowbridgii;* and internal organs of large insects in *S. yaquinae.*

Eleven of the 47 food categories occurred as one of the five top foods of at least one of the species of shrews. Five of these 11 items occurred as a major food in only one species: *Endogene* in *S. vagrans.* Amphibian flesh in *S. pacificus,* coleopterous larvae in *S. yaquinae,* and Ephemeroptera naiads and earthworms in *S. bendirii.* Centipedes were the most important food (15.4 percent volume) of *S. trowbridgii* and second in importance for *S. pacificus* (10.7 percent volume); but were of little importance in the other three species. Spiders were of little consequence in the diet of *S. pacificus,* but were major foods of the other four species. Invertebrate internal organs were the main food of *S. yaquinae* (28.6 percent volume), third in importance (10.5 percent volume) for *S. trowbridgii,* but were seldom eaten by other shrews. Mayfly (Ephemeroptera) naiads, important in the diet of *S. bendirii,* were not found in any of the other species. Larval insects, collectively, varied greatly between species, ranging from 9.9 percent by volume in *S. trowbridgii* to 45.5 percent by volume in *S. bendirii.*

The fact that centipedes were the most important food of *S. trowbridgii* is understandable since they both are most abundant around and under logs. Furthermore, the diet of *S. trowbridgii* reflects its adaptability to the wide range of microhabitats that it occupies; it was the only shrew to consume all 47 types of foods. Slugs and snails formed nearly a third of the diet of *S. pacificus.* These large shrews can easily handle the snails that are so abundant in their habitat as evidenced by the numerous snail shells left as refuse in the areas occupied by this shrew. The Pacific shrew appears to

feed fairly often on amphibians (amphibian flesh was found in four out of 30 individuals —6.1 percent by volume). There were three common amphibians small enough as adults for a Pacific shrew to be able to kill—the Pacific treefrog, *Hyla regilla,* the clouded salamander, *Aneides ferreus,* and the Oregon salamander, *Ensatina eschscholtzi.* Although no amphibian flesh was found in the stomachs of *S. yaquinae,* other flesh (probably mammal or bird) made up 3.9 percent of the volume. Insect larvae totaled 28.6 percent of the volume of material in the stomachs of this species. *Sorex pacificus* is an inhabitant of a gentler, more moderate habitat and climate than is *S. yaquinae,* which may, in part, account for differences in food habits. However, snails are more abundant along the southern Oregon coast and *S. pacificus* is also larger than *S. yaquinae* and has stronger teeth. *Sorex bendirii* is the most specialized in food habits, having eaten only 26 of the 47 types of food. *S. bendirii* is the only shrew of the five that had either mayfly naiads or earthworms as a top food, reflecting the aquatic habits of the species. The total volume of insect larvae and naiads was 45.5 percent by volume, far higher than in any other species of shrew examined.

Conclusions

A study of the habitat interrelationships of shrews in western Oregon, particularly along the coast, reveals that the shrews are primarily inhabitants of successional-stage plant communities; however, micro-habitat selection as well as the partitioning of the available food supply allows these small mammals to co-exist with a minimum of direct competition.

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Natality of Black-tailed Deer in McDonald State Forest, Oregon[3]

Abstract

Natality of black-tailed deer (*Odocoileus hemionus columbianus*) in McDonald State Forest was evaluated by examination of 147 reproductive tracts. Yearlings collected from November 1968 to May 1970 averaged 0.79 corpora lutea per doe and adults averaged 1.76. Yearlings collected during spring in 1969 and 1970 averaged 0.88 fetus per doe; adults averaged 1.61 fetuses per doe. Fetuses and corpora lutea were absent in fawns. The peak of breeding, established from ovarian examination in late fall, occurred from 1 to 16 November during both years of study.

Deer collected following a severe winter in 1968-69 had an index of condition based on kidney fat significantly lower than deer collected following a mild winter in 1969-70. The rates of ovulation and fetuses per doe following the more severe winter were lower than those following the mild winter, but the differences were not statistically significant. Apparent dates of breeding as estimated from embryonic development differed between 1969 and 1970. However, examination of ovaries collected in October and November could establish no difference between years in the timing of ovulation. The later estimate of dates of ovulation determined from embryonic development and reduced index of condition reflected poorer physical condition of the does and reduced growth of fetuses during the severe winter of 1968-69.

Introduction

The purpose of this report is to provide a record of changes in natality of black-tailed deer occupying the McDonald State Forest in Benton County, Oregon, during 1969 and 1970, and a record of relationships among weather, physical condition of the deer, and natality.

Description of the Study Area

McDonald State Forest (including Paul Dunn Forest) encompasses 5,171 ha of forested hills in the Coast Range approximately 11.3 km north of Corvallis, Oregon. Most of the area is 152-427 m above sea level; maximum elevation is 661 m.

McDonald Forest is in the hemlock (*Tsuga heterophylla*) vegetative zone described by Franklin and Dyrness (1969). The predominant community type is Douglas-fir/ocean spray (*Pseudotsuga menziesii/Holodiscus discolor*). The predominant soil type is "Red Hill" (Gartz, 1954), which occurs over much of the Coast Range. The stages of plant succession range from recently logged by the clearcutting method to subclimax vegetation. Eighty-four percent of the Forest is occupied by seral communities more than 30

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years old. Black-tailed deer generally occur in greatest density in seral communities less than 30 years old.

The climate is normally mild (U.S. Department of Commerce, 1969). Rainfall averages 1.02 m annually, and periodic summer drought is expected. Average temperature during January, the coldest month, is 4.1°C. Measurable snowfall at Corvallis occurs an average 83.5 days per year. Depth of snow on the ground rarely exceeds 5.1-7.6 cm at the lower elevations on the study area, and snow usually melts in one or two days.

Precipitation during December through February 1968-69 was 71.8 cm, snowfall totaled 78.2 cm, and the mean temperature was 2.9°C (Corvallis State College [sic] Weather Station, U.S. Department of Commerce, 1969, 1970). Values for 1969-70 were 84.0 cm of total precipitation, a trace of snow, and mean temperature of 5.8°C. Long-term normals for the reporting station were 44.9 cm precipitation, 15.4 cm snowfall, and mean temperature of 5.0°C.

Methods

Hunters were provided with a plastic bag and an illustration of the reproductive tract of female deer, and were asked to submit tracts from does for examination. Fifty-six pairs of ovaries were obtained during 1968, 16 in October, and 40 during November. Forty pairs were obtained during November 1969. Hunting of antlerless deer was not permitted during October 1969, but 11 does were collected from the area to provide a sample for comparison with the previous year.

Twenty does were collected in March-May 1969 and 1970, providing 40 reproductive tracts for examination during the later stages of gestation. Ovaries were sectioned at 1-mm intervals following brief storage in formalin and examined according to the procedure outlined by Trauger and Haugen (1965).

Mandibles were removed from deer brought to the checking station, except infrequently when a hunter objected. Jaws were marked, cleaned, and used to assign animals to fawn, yearling, and adult categories according to tooth replacement (Moreland, 1952). Jaws of adults were then separated comparatively into categories by degree of wear and assigned to age classes.

Both kidneys, with accompanying deposits of fat, and one femur were obtained from each deer in the March-May collections to appraise general physical condition. The ratio of kidney fat to kidney weight (Riney, 1955), color and texture of marrow from femurs (Riney, 1955), and compressability of a 6.4-cm section of marrow (Greer, 1968) were used as indices of body condition of the deer.

Results

Only 25 percent (5/20) of the ovarian pairs from adult does obtained during October 1968 and 1969 had corpora lutea. However, 91 percent (62/68) of the adult does collected during November had ovulated. Because significantly fewer deer collected in October had ovulated as compared with those collected in November ($P < 0.005$; $X^2 = 40.13$; d.f. $= 1$), rates of ovulation in the fall were estimated from ovaries collected during November. No significant differences ($P > 0.93$; $X^2 = 0.14$; d.f. $= 1$) occurred between years in mean numbers of ovulations per doe collected during November. Average numbers of corpora lutea showed greater variability among yearlings than adults (Table 1).

TABLE 1. Average numbers of corpora lutea per doe (±2 standard error) from deer collected in McDonald Forest, Benton County, Oregon. (Sample sizes in parentheses.)

Period of collection	Fawns	Yearlings	Adults
November 1968	0.00 (8)	0.89 ± 0.47[a] (9)	1.74 ± 0.30 (23)
Spring 1969	0.00 (2)	0.67 ± 0.54 (6)	1.75 ± 0.48 (12)
November 1969	0.00 (8)	0.57 ± 0.49 (7)	1.76 ± 0.21 (25)
Spring 1970	0.00 (2)	1.50 (2)	1.81 ± 0.35 (16)
Mean		0.77 ± 0.25 (24)	1.76 ± 0.32 (75)

[a] The formula $L(u) = \pm t(.05)\ s$ (Senedecor and Cochran, 1956-76) was used to calculate standard errors provided in the tables.

The average number of fetuses per adult doe (Table 2) was slightly lower than the average number of corpora lutea per adult doe, but the confidence intervals overlapped.

TABLE 2. Average number of fetuses per doe (±2 standard error) from deer collected in McDonald State Forest, Benton County, Oregon. (Sample sizes in parentheses.)

Period of collection	Fawns	Yearlings	Adults
1969	0.00 (2)	0.67 ± 0.54 (6)	1.50 ± 0.43 (12)
1970	0.00 (2)	1.50 (2)	1.69 ± 0.32 (16)
Mean	0.00 (4)	0.87 ± 0.53 (8)	1.61 ± 0.24 (28)

The initiation and peak of the breeding season were determined from the appearance of corpora lutea in ovaries collected during the fall. The does in McDonald Forest began breeding in the last half of October and reached a peak in the first half of November (Table 3).

TABLE 3. Percentage of yearling and adult black-tailed deer which had ovulated by time of collection from McDonald State Forest, Benton County, Oregon. (Sample size in parentheses.)

	Percentage having ovulated	
Date of collection	1968	1969
October 17-25	14.3 (7)	14.3 (7)
October 26-November 7	28.6 (7)	66.7 (3)
November 8-10	94.1 (17)	87.5 (32)
November 16-17	93.3 (15)	—

Differences in Physical Condition Between Years. Only four of 39 deer examined had indices of kidney fat of 30 percent or greater (Fig. 1). Indices of condition based on kidney fat from deer collected in 1970, however, were significantly higher ($P > 0.025$; $X^2 = 10.18$; d.f. $= 1$) than the indices from deer collected in 1969 (Table 4).

TABLE 4. Numbers of deer collected in McDonald State Forest, Benton County, Oregon, in relation to index of condition with calculated expected frequencies in parentheses.

	Index of condition (percent)			
Year	4-7	8-12	13-17	18+
1969	9 (5.35)	6 (4.87)	3 (5.35)	1 (3.41)
1970	2 (5.65)	4 (5.13)	8 (5.65)	6 (3.59)

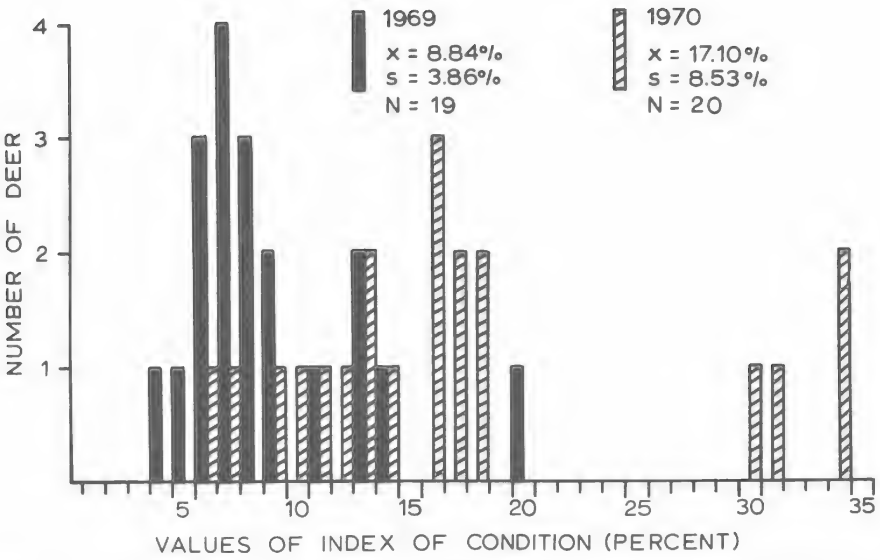

Figure 1. Indices of physical condition of deer collected March-May 1969 and 1970, McDonald State Forest, Benton County, Oregon. Index of condition equals weight of fat surrounding kidney ÷ kidney weight X 100.

Rate of fetal growth may be used as an indicator of physical condition of the deer collected because rate of growth of the fetus depends on the level of maternal nutrition (Ommundsen and Cowan, 1970). We suggest that the earlier estimated dates of breeding based on fetal length in 1969 resulted from a faster rate of growth than that achieved by fetuses conceived in 1968 when the estimates of dates of breeding obtained by frequency of ovulation and fetal lengths overlapped. Faster rate of growth of a fetus would result in an earlier estimated date of breeding because the date of breeding was estimated from the length of the fetus. In 1968, 95 percent of the does were estimated on the basis of fetus length to have bred between 23 October and 2 December (Fig. 2), with a mean date of 14 November. In 1969, the mean date of conception was calculated, by the same method, as 4 November, with 95 percent of the does estimated to have bred between 19 October and 20 November. The estimated dates of breeding based on fetus length in 1969 were significantly earlier ($P < 0.025$; $X^2 = 9.42$;

TABLE 5. Groupings of black-tailed deer according to estimated dates of breeding, 1968-69, McDonald State Forest, Benton County, Oregon, with calculated expected frequencies in parentheses.

Year of collection	October 17-31	November 1-8	November 9-14	November 15+
1969	1 (3.3)	2 (3.75)	6 (4.7)	6 (3.3)
1970	6 (3.7)	6 (4.25)	4 (5.3)	1 (3.7)

d.f. = 1) than those in 1968 (Table 5). Because there were no apparent differences in the numbers of corpora lutea at the same time each fall (Table 3), actual dates of breeding were probably similar for 1968 and 1969.

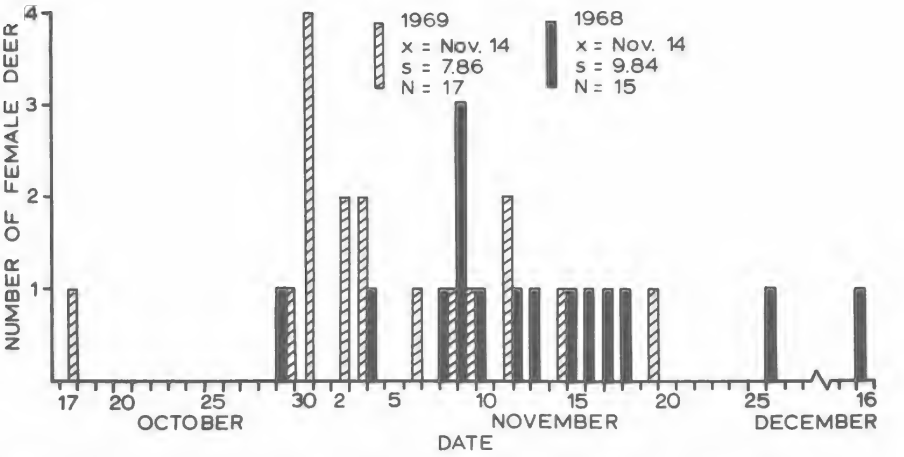

Figure 2. Dates of conception of black-tailed deer collected March-May 1969 and 1970, McDonald State Forest, Benton County, Oregon. Dates determined by backdating from date of collection on basis of fetal development.

The statistically significant differences in both indices of condition and in fetal growth rates between years support the hypothesis that deer collected in 1970 were in better condition than deer collected in 1969 following the harsh winter. The more rapid rate of growth exhibited by fetuses in 1969 would provide a larger and stronger fawn at birth.

Discussion

The rate of ovulation of adult does collected in McDonald Forest was midway between the lowest and highest rates of ovulation found by Bischoff among five herds of black-tailed deer in California (Table 6). The average number of corpora lutea found by

TABLE 6. Comparison of rates of ovulation among black-tailed deer herds in California, Washington, and McDonald State Forest, Oregon. (Sample sizes in parentheses.)

	Corpora lutea per doe	
Authority	Yearling	Adult
McDonald State Forest	0.79 (24)	1.76 (76)
Bischoff (1958)		
Tehama	—	1.91 (22)
Oak Knoll	—	1.54 (22)
Taber (1953)		
Recent Burn	0.67	1.75
Open Brush	1.00	1.89
Brown (1961)	1.15 (13)	1.57 (46)

Taber (1953) among deer collected from a recently burned area in California, which he considered fair range, was almost identical with the rate of ovulation from deer collected in McDonald Forest. Deer collected from open brush land, which Taber (1953) considered good range, had a slightly higher number of ovulations than deer collected from McDonald Forest. The number of ovulations per adult doe killed in

McDonald Forest was slightly higher than the number found at comparable times of year in western Washington (Brown, 1961). The rate of ovulation in McDonald Forest may have been influenced by the high average rate of harvest (34 per ha per year) over the past 19 years.

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Herpetofauna of Yakawawa Canyon, Washington

Abstract

A two-month study was conducted on the herpetofauna in Yakawawa Canyon, southeast Washington, to obtain information on occurrence, distribution, and climatic factors possibly affecting the animals' altitudinal distribution. Observations were obtained by several techniques which are described.

Five species were collected or observed including the Pacific treefrog, *Hyla regilla;* western toad, *Bufo boreas;* western skink, *Eumeces skiltonianus;* great basin gopher snake, *Pituophis melanoleuces;* and the western rattlesnake, *Crotalus viridis.*

Amphibians were first observed on 31 March near the canyon bottom, but reptiles were not collected until 9 May. Amphibians were most numerous in the bottom, open half of the canyon and were noted in the upper half on only four occasions. Mean temperature and relative humidity of the upper canyon were 8.2°C and 75.4 percent, and for the bottom of the canyon 10.2°C and 75.2 percent. Evidently air temperature influenced activity of the herpetofauna, but atmospheric water vapor had little or no effect on amphibians observed.

Introduction

Numerous studies of the amphibian and reptilian fauna have been conducted in southeastern Washington. Most of these investigations have recorded various species from the prairies and from the area immediately adjacent to the Snake River, but none has surveyed the varied habitats of the highly dissected lands that extend from the Snake River to the prairies 600 m above. This study examines one canyon of this transitional zone in an attempt to identify what amphibians and reptiles live there, how their distribution varies with the habitats encountered, and whether differences in temperature and relative humidity exist between the top and bottom of the canyon and if so, whether these differences affect faunal distribution.

Yakawawa Canyon, Whitman County, Washington (R44E, T13N) was chosen for study as it provides a wide variety of habitats, has a year-round stream, and is of sufficient length to reach well up into the Palouse Prairie. There has not been extensive overgrazing in this canyon as has happened in many of the canyons of the Snake River. This study should be continued annually to follow changes that may result from possible further intervention by man. This project can also serve as the basis for other studies on the effects of impoundments of the Snake River on the riparian habitats as it was undertaken during the period immediately following impoundment of Lower Granite Reservoir in February, 1975.

Six species of amphibians have been recorded from the Snake River Canyon in the vicinity of Yakawawa Canyon. These include *Ambystoma macrodactylum, Scaphiopus intermontanus* and *Bufo boreas* by Slater (1955); *Bufo woodhousei* by Metter (1960); and *Hyla regilla* and *Rana catesbeiana* by Svihla (1933). Eight species of reptiles have been reported, including *Sceloporus graciosus,* and *Coluber constrictor* by Slater (1963);

and *Phrynosoma douglassi, Eumeces skiltonianus, Diadophis punctatus, Pituophis melanoleucus, Thamnophis sirtalis,* and *Crotalus viridis* by Svihla and Svihla (1933). An unpublished study by the Army Corps of Engineers has recently listed *R. catesbeiana, R. pretiosa, H. regilla, S. intermontanus, B. woodhousei, Chrysemys picta, E. skiltonianus, C. constrictor, T. elegans, T. sirtalis, C. viridis, P. melanoleucus, S. graciosus,* and *Uta stansburiana* from the area of the Snake River between Lewiston, Idaho, and the Columbia River. In addition, according to the ranges in Stebbins (1966), the following species could probably be collected from the area: *Ambystoma tigrinum, R. pipens, S. occidentalis, C. bottae,* and *M. taeniatus.* There have been no recent reports of *B. woodhousei* in the Whitman County section of the Snake River and there may not be a resident population in this area at present.

Methods and Materials

This investigation was carried out between 29 March and 13 May, 1975 in Yakawawa Canyon. Eight pit traps were constructed at approximately 90 m intervals in altitude. The traps consisted of a 2.4-3.1 m by 30 cm lengths of 6.3 mm hardware cloth which directed organisms into a 10.4 l bucket buried level with the surface of the ground. The traps were attended twice weekly. Live animals were noted and released; dead amphibians and reptiles were fixed in 10 percent formalin and later transferred to 70 percent ethanol. Each pit was shaded with cardboard squares to reduce chances of dessication and predation of trapped specimens. Portable recording hydrothermographs (Friez Model 594) were set up at the top and bottom of the canyon to give a continuous record of temperature and relative humidity throughout the study period. Approximately nine hours per week were spent in the canyon with about 1/3 of the total time allotted to checking traps and the remainder spent in active search for amphibians and reptiles. The effects of temperature and vapor pressure deficit on the abundance of the amphibians were analyzed using simple linear regression and the resultant correlation coefficients checked at both the 5 percent and 1 percent levels for significance. In performing the regression analysis, only the amphibians observed in the bottom half of the canyon were used and these were plotted against data for the bottom hydrothermograph. This procedure was followed because only four observations of amphibians were made in the upper canyon. Reptiles were not included as a result of the low number of observations. Vapor pressure deficits were obtained with the following formula: Vpd=Vps (1–RH) where Vpd=vapor pressure deficit and Vps=saturation vapor pressure at °C for the relative humidity (RH) observation used.

Results

The herpetofauna observed in the canyon consisted of five species, *H. regilla, B. boreas, E. skiltonianus, P. melanoleucus,* and *C. viridis.* Table 1 gives the number of amphibians and reptiles observed during each sampling period and Table 2 indicates the maximum and minimum temperatures and relative humidity for the sampling days. The mean maximum and minimum temperatures and relative humidity at the top of the canyon were 14.3° C and 2.1° C and 99.2 percent and 51.2 percent, respectively. The high temperature recorded at the top was 28.3° C and the low temperature was –2.2° C. At the bottom the mean high temperature was 15.8° C and the mean low temperature was 4.4° C. The highest temperature recorded at the bottom was 27.2° C and the

lowest was 0.6° C. The mean maximum and minimum relative humidity at the bottom was 99.4 percent and 51.0 percent.

TABLE 1. Number of organisms observed per collection date.

	Date													
	March		April							May				
Species	29	31	4	11	16	19	22	26	29	4	6	10	13	Total
Hyla regilla	—	1	—	1	—	1	8	3	6	2	6	9	8	45
Bufo boreas	—	—	—	—	2	1	1	2	—	2	—	3	5	16
Eumeces skiltonianus	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Pituophis malenoleucus	—	—	—	—	—	—	—	—	—	—	—	—	3	3
Crotalus viridis	—	—	—	—	—	—	—	—	—	—	—	—	3	3
Totals	0	1	0	1	2	2	9	5	6	4	6	13	19	68

TABLE 2. Temperatures and relative humidity for collection dates.

	Top				Bottom			
Date	Max°C	Min°C	Max RH %	Min RH %	Max°C	Min°C	Max RH %	Min RH %
March 29	—	—	—	—	11.7	5.0	97	57
" 31	7.2	–1.1	100	32	7.8	–0.6	100	74
April 4	16.7	0.0	100	40	11.1	0.6	100	62
" 11	18.9	0.0	100	50	23.3	2.2	100	40
" 16	12.8	0.6	100	62	15.0	8.3	100	52
" 19	8.9	2.2	100	46	14.4	5.0	100	47
" 22	16.1	2.2	100	24	18.3	6.7	100	47
" 26	16.1	5.6	100	40	19.4	7.2	100	49
" 29	18.3	0.0	100	34	17.8	1.1	100	38
May 4	12.2	1.1	100	42	13.3	3.3	100	44
" 6	16.7	3.3	100	45	17.2	5.0	100	54
" 10	25.0	5.0	100	35	27.2	8.3	100	32
" 13	28.3	7.2	100	42	26.1	11.7	100	42
Means	16.4	2.2	100	41	17.1	4.9	99.8	49.1

There was a total of 68 observations (audio or visual) of amphibians and reptiles during the study period. Of these only four were made in the upper half of the canyon and only one was made in the wooded areas next to the stream.

Simple linear regression of the data revealed that the number of amphibians observed was closely related to the daily mean temperature but not to the vapor pressure deficit. Correlation coefficients for these two relationships were 0.81 for temperature and 0.78 for vapor pressure deficit.

Discussion

Yakawawa Canyon lies within two vegetation zones as described by Daubenmire (1970). The lower of these zones extending along the Snake River and well up into the surrounding canyons is the *Agropyron-Poa* zone. The very top of the canyon lies in the *Festuca-Symphorocarpos* habitat type. Yakawawa Canyon is approximately 4.5 km long and extends in an easterly direction from the Snake River from what was Bishop, Wash-

ington before the construction and filling of Lower Granite Reservoir (Fig. 1). The present level of the Snake River is about 210 m above sea level, and the top of the canyon is about 800 m above sea level. The south flank of the canyon is more heavily

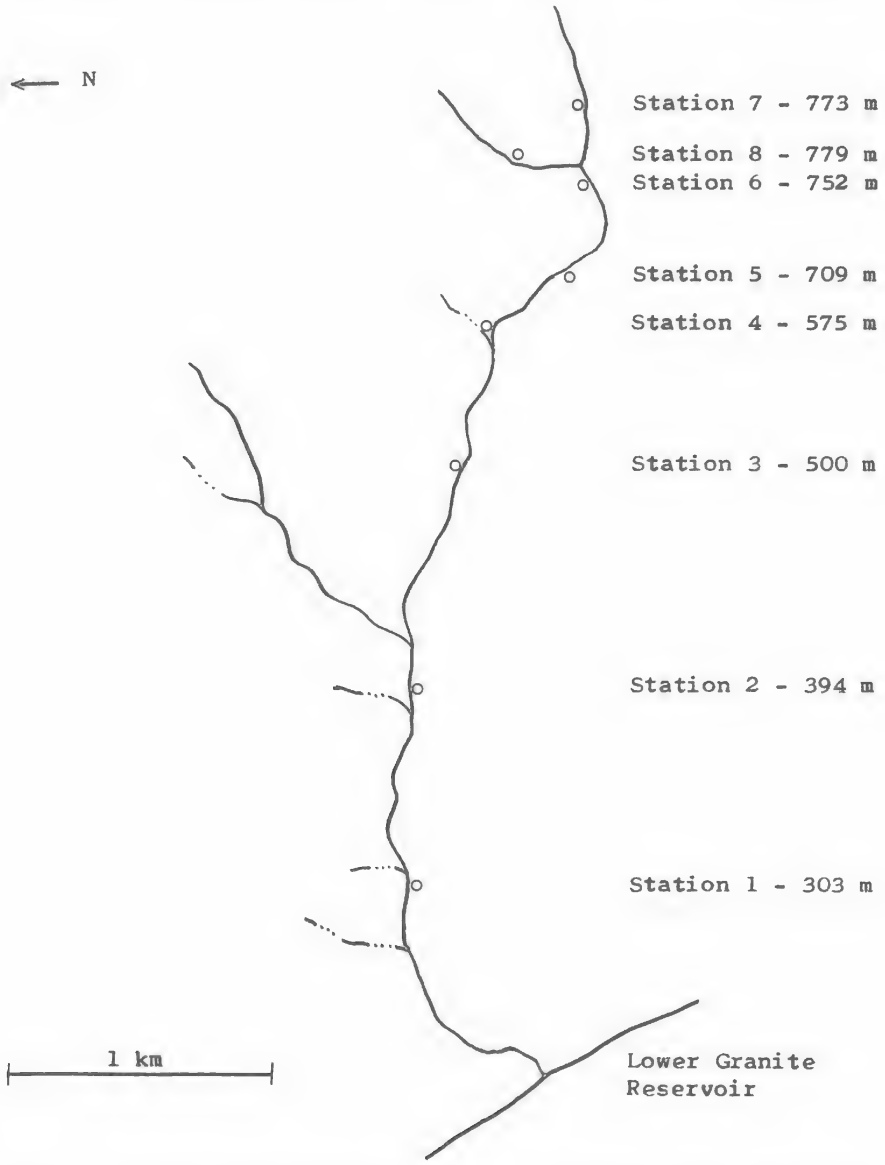

Figure 1. Yakawawa Canyon, Whitman Co., Washington. Locations (circles) and elevations of pit traps.

covered with grasses, *Rosa woodsii, Amelanchier alnifolia* and various low shrubs and scattered *Crateagus douglasii* and *Celtis douglasii* because of its north exposure. The northern flank is much more open with numerous patches of talus and appears to be grazed by cattle to a lesser extent. The floor of the canyon varies in width from about 50 m near the river to less than 5 m near station 4. The bottom is generally very rocky and only between stations 1 and 2 and in the area of stations 6, 7, and 8 is there any appreciable accumulation of soil.

Eight sites were selected for construction of pit traps in an attempt to sample all the major habitat types. Station 1, at an elevation of 303 m, was located on a broad, open, boulder-strewn stretch of the valley floor. There were numerous *Crateagus douglasii, Amelanchier alnifolia, Celtis douglasii, Rhus glabra,* and *Chrysothamnus nauseosus* in the area and *Heracleum lanatum* was common along the water course. The trap was set perpendicular to the stream and adjacent to a strip of exposed basalt below a steep bank of alluvium. At this station the stream was about 1 m wide and 18-30 cm deep. Site 1 was at the boundary between the more open stream bottom continuing to the river and an area of heavier cover extending upstream. Station 2 was located parallel to a part of the stream running through a pure *Alnus sp.* grove at an altitude of 394 m. These trees were about 8-10 m high and approximately 20 cm thick. The stream was about 1 m wide and not over 15 cm deep at the beginning of the study and had a reduced flow by the end of the period. There was a heavier accumulation of soil at this site, but there were numerous large rocks scattered about. The third station was in the open, narrow stream bed at an elevation of 500 m. The stream in this area flowed over exposed basalt with very little soil deposited along its course. There were numerous low falls with pools at their bases often more than 1 m deep. Other than grasses, there were some *Heracleum lanatum, Typha latifolia,* and *Salix sp.* along the stream. On the banks above, there were *Rosa sp.* thickets and *Amelanchier alnifolia.* Station 4 was located at the junction of the main stream and a small tributary falling from the wheat fields on the north rim of the canyon. The pit was located in an open grove of *Salix sp.* perpendicular to a 1 m wide by 30 cm deep pool at an elevation of 575 m. The area directly influenced by the stream here is narrow (about 5 m), but there was a deeper layer of soil and fewer rocks. The fifth pit trap was established in a deep, narrow part of the stream bed below a 6 m waterfall and 50 m above another 15 m fall. There were some *Rosa sp.* and grasses present but less vegetation because of a fairly constant "rain" of soil from the very steep banks. There were also some small *Salix sp.* and *Populus sp.* within 10 m of this trap. The elevation of site 5 was about 709 m. Stations 6, 7, and 8 were located at altitudes of 752 m, 773 m, and 779 m respectively. They were in the upper part of the canyon where the soil was much thicker and the floor wider. The stream was lined with many *Crateagus douglasii* with a few large *Salix sp.* (more numerous around station 7) scattered along the bottom. The sides of the canyon were covered with thickets of *Rosa sp.* and *Dipsacus sylvestris* and numerous *Rhus glabra, Amelanchier alnifolia,* and *Acer circinatum.*

Hyla regilla was the most numerous species of the herpetofauna. This treefrog was first recorded (by call) on 31 March near the bottom of the canyon when the temperature for the day was 7.8° C. This is well within the lower temperature limits for this species as Cunningham and Mullally (1956) found *H. regilla* calling down to 3.9° C. Egg masses of *H. regilla* were first observed on 19 April, between station 1 and

the river, about three weeks later than Metter's (1960) report of the usual onset of the breeding period for this species in the Whitman County area. The late initiation of breeding could be attributable to the unseasonably cool temperatures in the area during the spring of 1975.

Pickwell (1947) stated that the color of *H. regilla* depends on where they are found; but in Yakawawa Canyon solid bright green frogs were present in the same habitat with greenish brown individuals exhibiting grayish blotches. *H. regilla* was found almost exclusively in the bottom half of the canyon in the more open areas where the creek was slow enough to form occasional pools. These pools apparently were necessary for *H. regilla,* as this species was not found along fast flowing stretches of the stream without pools. One *H. regilla* call was the only record of a reptile or amphibian in the heavy, woody cover that was occasionally present along the stream.

Bufo boreas was the second most commonly observed herptile. This species was initially observed on 16 April, at station 1, where two juveniles were collected in the pit trap. Only two adults were observed before 13 May, one between stations 1 and 2 and the other at the top of the canyon. On 13 May, numerous adult males were seen congregating at a small pool which was being used extensively by *H. regilla* halfway between station 1 and the river. According to Metter (1960), *B. boreas* does not breed in the Snake River Canyon until July when the river has passed its spring high water stage and the toads can utilize the shallow pools left along the river. With the completion of Lower Granite Dam, the entire lower section of the river will be subjected to less fluctuations in water level. Consequently, the breeding sites utilized by this toad have been greatly altered if not entirely destroyed. This situation will result in a drastic reduction in the *B. boreas* population, if not its complete destruction, along this section of the Snake River. Other than the one adult, *B. boreas* was not found above station 4.

Pituophis melanoleucus and *C. viridis* were finally observed three times on 13 May, after six days with high temperatures averaging 20° C or above. Only one other reptile, *E. skiltonianus,* was seen and that was during the first part of the warm period just mentioned. The skink was found in the middle, rocky part of the canyon; whereas *P. melanoleucus* and *C. viridis* were found scattered over a wider area.

Temperature and habitat type apparently had a great effect on the distribution of the amphibians. The linear regression performed using mean daily temperature (Fig. 2) had a correlation coefficient of 0.81. The correlation coefficient for the daily high temperature versus number of amphibians was 0.78. Both are significant at the 1 percent level with 11 df.

A simple linear regression was also conducted on vapor pressure deficit (vpd) for the collection days versus number of amphibians observed. This parameter was analyzed since evaporation is more nearly proportional to vpd than to relative humidity (Odum, 1971) and evaporative rates are undoubtedly very important to amphibians. The correlation coefficient for vpd was 0.78 for 11 df which is significant at the 1 percent level. The positive correlation (Fig. 3) indicates that vpd did not have a negative effect on the amphibians as it was greatest at the higher temperatures which is also where most amphibians were observed. Apparently *H. regilla* and *B. boreas* were not much affected by changes in atmospheric water levels during this period. This result is not too surprising: the stream was a constant source of water and these two species are known to be fairly well adapted to more arid conditions.

Of the four sightings of amphibians in the upper half of the canyon, only one was in the thickly wooded section of the stream. This observation, along with seeing no amphibians in the more heavily wooded sections of the bottom half of the canyon, suggests that *H. regilla* and *B. boreas* prefer the more open habitat, at least during the spring breeding season. The sighting of only four amphibians in the upper half of the canyon is also not too surprising: the top half is more heavily wooded; there are fewer small pools in the stream for breeding; and it was cooler by 1.5° C during the day and 2.3° C at night.

Yakawawa canyon is one of the few large canyons along this part of the Snake River that has not been severely disturbed by man. Now is the time for one of these canyons

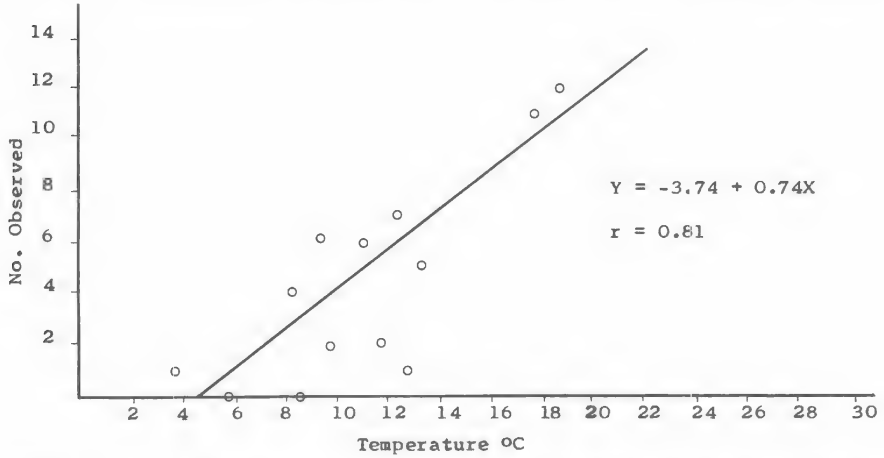

Figure 2. Simple linear regression of number of amphibians observed versus daily mean temperature at bottom for collection dates.

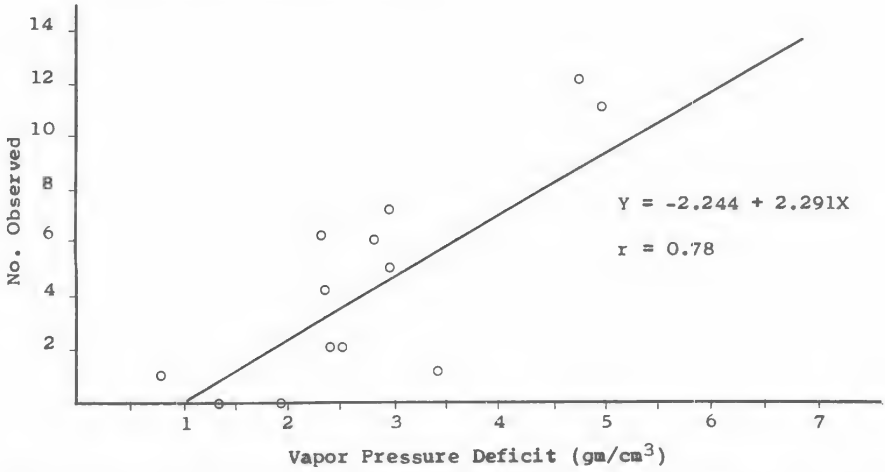

Figure 3. Simple linear regression of number of amphibians observed versus vapor pressure deficits at bottom for collection dates.

to be preserved in its natural condition, not only for studies of these conditions, but as a reference point for future studies on man's effects on these areas.

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ERRATA

Wiederholm, T. A Survey of the Bottom Fauna of Lake Sammamish. NW SCIENCE, Vol. 50, No. 1, 1976.

Page	Line	Reads	Should read
24	27	The most characteristic of this species	The most characteristic benthic species in the lake is *Chironomus atritibia*. The identification of this species
Table 2, line 2		St. 3 St. 6 St. 9	St. 3 St. 6 St. 2
Table 2			Abundance values for Oligochaeta should be transposed with those for *Pisidium* under 15 m stations
31	9	abundant occurrence of nutrient factors	abundant occurrence of *Ch. atritibia*, an important mesotrophic indicator species, suggests that nutrient factors

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Microclimatic Patterns on the Arid Lands Ecology Reserve

Abstract

Cluster analysis of correlation coefficients is employed to detect microclimatic patterns within a 27-station network in a topographically diverse region of southeastern Washington. Correlations among stations based on 6 years of monthly maximum and minimum temperatures range between 0.95 and 0.99; those based on monthly precipitation range from 0.85 to 0.98. When all three variables are combined into a single statistic, correlations range from 0.95 to 0.99. In addition to gross topographical influences, such as elevation and aspect, microclimates were influenced by (1) concave microtopography, (2) nearness to a major river valley confluence, and possibly (3) wind differences.

Introduction

Within zonal climates, which are determined by latitude, distance from oceans, and elevation, lie a multitude of microclimates, which are largely distinguished by localized differences in slope, exposure, elevation, and local topography. Plants and animals usually are adapted to the zonal climates, but they must live in or avoid the microclimates. The spectrum of microclimates in a landscape is thus an important part of the structure of ecosystems. On the Arid Lands Ecology Reserve, a study of microclimates in a hilly region of a cold desert shrub-steppe has led to some understanding of the relationships between microclimates and the physical elements which determine them.

The Arid Lands Ecology Reserve is a large section of the Hanford Reservation dedicated to study of arid ecosystems by the U.S. Atomic Energy Commission (since subsumed by the Energy Research and Development Administration) in 1968. The ALE Reserve lies on the western edge of the Lower Columbia Basin in southeastern Washington, ranging in elevation from about 140 m to 1100 m. The dominant vegetation is *Artemisia/Agropyron* shrub-steppe (Daubenmire, 1970). Shortly after the creation of ALE, a 27-station network (Fig. 1) was set up to collect basic climatic data in a variety of habitats. The data consist of monthly total precipitation and maximum and minimum temperatures. These data are understandably restricted in utility, but simple enough to acquire to assure continuous collection through time over a broad area. The data have been recorded monthly from October 1968 to the present and provide a suitable basis for the study of microclimates in and near the Rattlesnake Hills.

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Methods

Although gross climatological effects may be observed by examining isohyets and isotherms, elucidation of the more subtle microclimates requires different techniques. We have chosen to employ cluster analysis of similarity coefficients, a technique taken from numerical taxonomy (Sokal and Sneath, 1963).

To determine the similarity in pattern between any two stations, we calculated

Figure 1. Arid Lands Ecology Reserve. Numbers refer to ALE Micrometeorological Network sampling stations.

the product-moment correlation coefficient (see, for example, Sokal and Rohlf, 1969) for all the past months ($n = 72$) for each of the three sets of data. These similarities (or correlations) between all possible pairs of stations were arranged into three matrices (one for each climatic data set), then reduced by means of weighted pair-group cluster analysis (Sokal and Sneath, 1963) as follows:

(1) the two sites with the highest similarity were combined to form the first cluster (A +B);

(2) the new similarities between this cluster and each of the remaining sites (Q) were calculated using the Spearman sums-of-variables method,

$$r_{(A+B)Q} = \frac{r_{AQ} + r_{BQ}}{\sqrt{2 + 2\,(r_{AB})}}$$

where r_{AB} is the similarity between unit A and unit B;

(3) steps (1) and (2) were repeated until all sites were clustered, with the new cluster now considered a single unit.

The Spearman sums-of-variables method is used in lieu of simple averages to reduce bias, since the variance of the correlation coefficient is dependent on its magnitude (Sokal and Sneath, 1963).

Each of the three separate measures of microclimate interact to make up part of the environment in which plants and animals live. To average the three correlation coefficients for each pair of stations into one number indicative of their overall microclimatic similarity, we first subjected the correlations to Fisher's z-transformation (Sokal and Rohlf, 1969). This transformation seemed desirable because the distribution of correlation coefficients is skewed while that of the z-statistic is normal. We then averaged the three z-statistics and transformed this average back into an average correlation or similarity. We then re-applied the clustering techniques to this average similarity to produce combinations of stations with similar patterns of overall microclimate.

Clusters resulting from each of the four similarity matrix reductions are geographically delimited by encircling on a map the stations belonging to each. In this way a map much like a topographic map may be built up, only now isolines enclose areas of equal or greater microclimatic pattern similarity, rather than equal or higher elevation. The similarity levels at which we wish to define groups and to separate out subgroups are arbitrary, for there is no convenient method to test for statistical differences between groups.

Results

Not surprisingly, correlations within all four data sets were quite high, confirming the notion that climatic patterns are basically the same all over the Reserve. Similarities between stations for maximum and minimum temperatures generally ranged between 95 and 99 percent, as did those for the overall analysis. Similarities for monthly precipitation were more variable, ranging from 85 to 98 percent. Because of the large sample sizes involved, standard errors of the correlation coefficients were quite small; differences in correlation coefficients as small as one tenth of a percent were statistically significant ($P \leq 0.01$).

Maximum Temperatures. Clustering of stations based on maximum temperatures, illustrated by the dendrogram in Figure 2, shows two large groups distinguishable at 98 3/4 percent, plus a single anomalous site, station 15 (the relation between dendrograms and maps is the same for each data set, so other dendrograms will not be shown). Plotted on a map, the two major groups clearly resolve themselves into high and low elevation stations (Fig. 3A). Interestingly, the altitudinal range within the high elevation group (1 in Fig. 3A) traverses over 800 m (from about 300 m

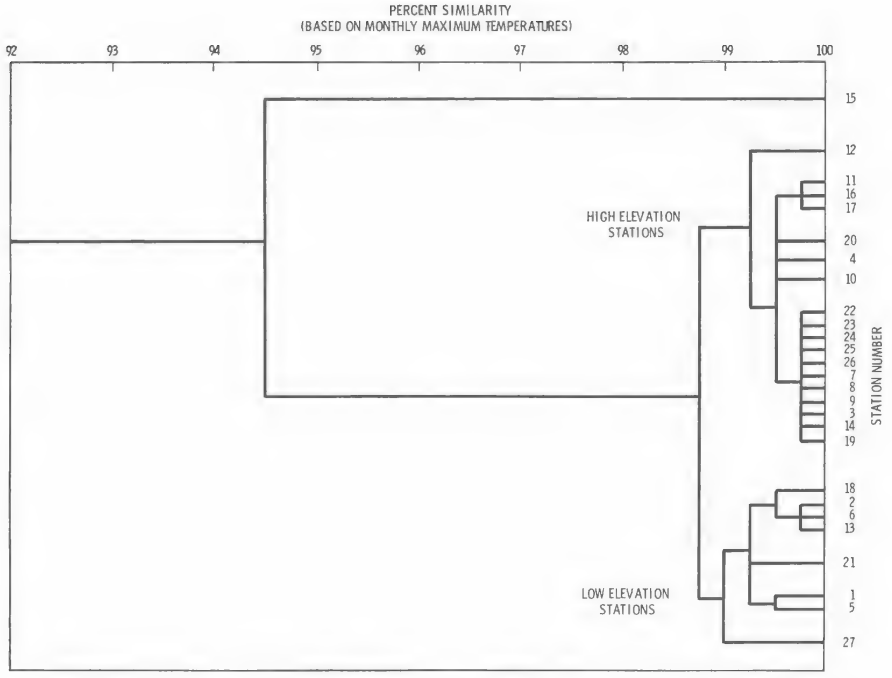

Figure 2. Dendrogram representing the results of cluster analysis of ALE micrometeorological stations on the basis of similarity of monthly maximum temperatures. Stations numbered as in Figure 1.

to 1100 m), while the low elevation stations (Fig. 3A:2) range only from 140 m to 200 m. Further, within each of the major groups minor groupings are evident, although in some instances a "group" consists of but a single station. At lower elevations, the Cold Creek Valley breaks down into three subgroups (Fig. 3B:1), with a lone station out in the flats forming a fourth (Fig. 3B:2). Altitudinal bands appear much more pronounced in the higher elevation subgroups (Fig. 3C). The largest subgroup (Fig. 3C:1) is at mid-elevation, averaging 370 m; the next (Fig. 3C:2) is slightly higher, about 610 m. Three stations on the crest of Rattlesnake Mountain (1100 m) form the highest elevation subgroups (Fig. 3C:3), and a station with a southern exposure on the west side of the crest forms the fourth (Fig. 3C:4). The single anomalous station is located on a steep northern exposure just a few meters below the crest, lying in a well-protected area (Fig. 3A:3).

Minimum Temperatures. The patterns of minimum monthly temperatures are quite different from the preceding ones, and not as easily defined. Three clear-cut groups, however, do emerge (Fig. 3D). One is at middle elevations and encompasses 11 stations (Fig. 3D:1); the second, at the highest elevations, includes station 15, which we showed earlier to be anomalous with respect to maximum temperatures (Fig. 3D:2). The third group consists of three stations in the valley floor located in gentle depressions or "frost pockets" (Fig. 3D:3). The eight remaining stations, which covered virtually all elevations, are each more or less distinct.

Precipitation. Precipitation patterns showed the greatest variability of the three measures we considered, forming one large group at the 98 percent level (Fig. 3E:1). This group consists of all but five stations: of these five, two low elevation stations are loosely allied with the main group; the other three are those on the ridge crest, with station 15 again the most distinct (Fig. 3E:2). Within the large group occur five distinct subgroups (Fig. 3F). These include: (1) low level stations, (2) middle elevation stations, (3) high elevation stations, (4) middle and high elevation stations at the southern end or edge of the Rattlesnake Hills, and (5) a single low elevation station at the edge of the Hills. Apparently, both elevation and proximity to the edge of the mountain affect precipitation patterns more or less equally. The cluster at the edge of the Hills lies at right angles to the isohyets in that area, suggesting that the *amount* of precipitation is not influential here.

Temperature and Precipitation Combined. Four major groups emerge from the overall analysis combining maximum and minimum temperatures and precipitation (Fig. 4A): (1) a protected high elevation site which resembles Palouse grasslands; (2) a site far removed from the mountain, well into the cold desert shrub-steppe of the Columbia Basin; (3) low elevation stations in concave topography; and (4) all other stations, both high and low elevations. This latter large group contains within it distinct sub-subgroups (Fig. 4B): (1) the high elevation, steep, windswept ridge top; (2) the single high elevation site with a southern exposure; (3) mid- to high-elevation stations in steep topography; (4) mid- to low-elevation stations in moderate topography; and (5) a group of three stations at the southern end of the hills.

Discussion and Conclusions

This exercise has provided several insights into the patterns of microclimates exhibited in the Rattlesnake Hills and the flats below them. For example, consider the map of

overall microclimates (Fig. 4B): within the mid-elevation group occurs a very well-defined cluster consisting of three stations (Fig. 4B:5; sites 22, 23, 24, Fig. 1). This subgroup lies at the southeastern end of the Hills, covering elevations from about 180 m to 330 m. This end of the Hills lies at the confluence of two major valleys—the Yakima River Valley and the Lower Columbia Basin. These three stations always appear within the same cluster, whether for maximum or minimum temperature or

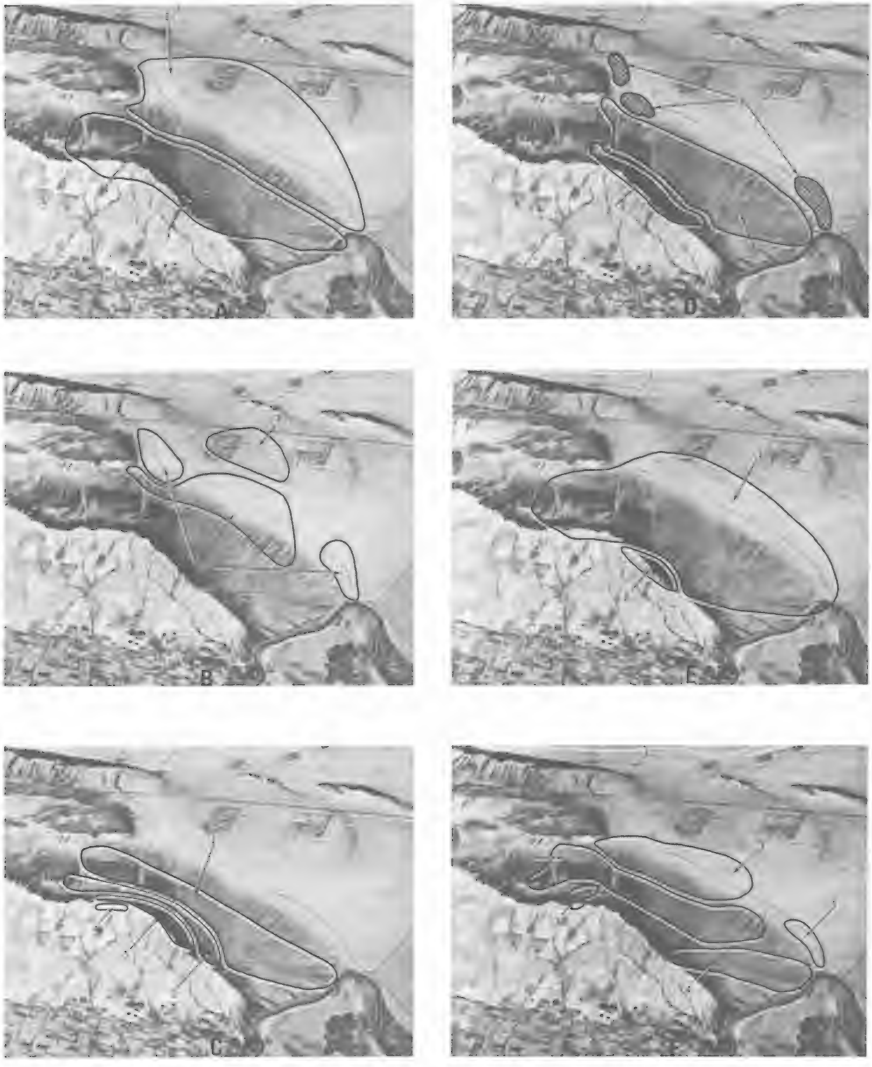

Figure 3. Results of independent cluster analyses of each microclimatic variable: A. monthly maximum temperatures, major clusters; B. monthly maximum temperatures, lower elevation subgroups; C. monthly maximum temperatures, higher elevation subgroups; D. monthly minimum temperatures, major clusters and "frost pockets"; E. monthly precipitation, major clusters; F. monthly precipitation, lower elevation subgroups. Clusters and subgroups designated by number referred to in the text.

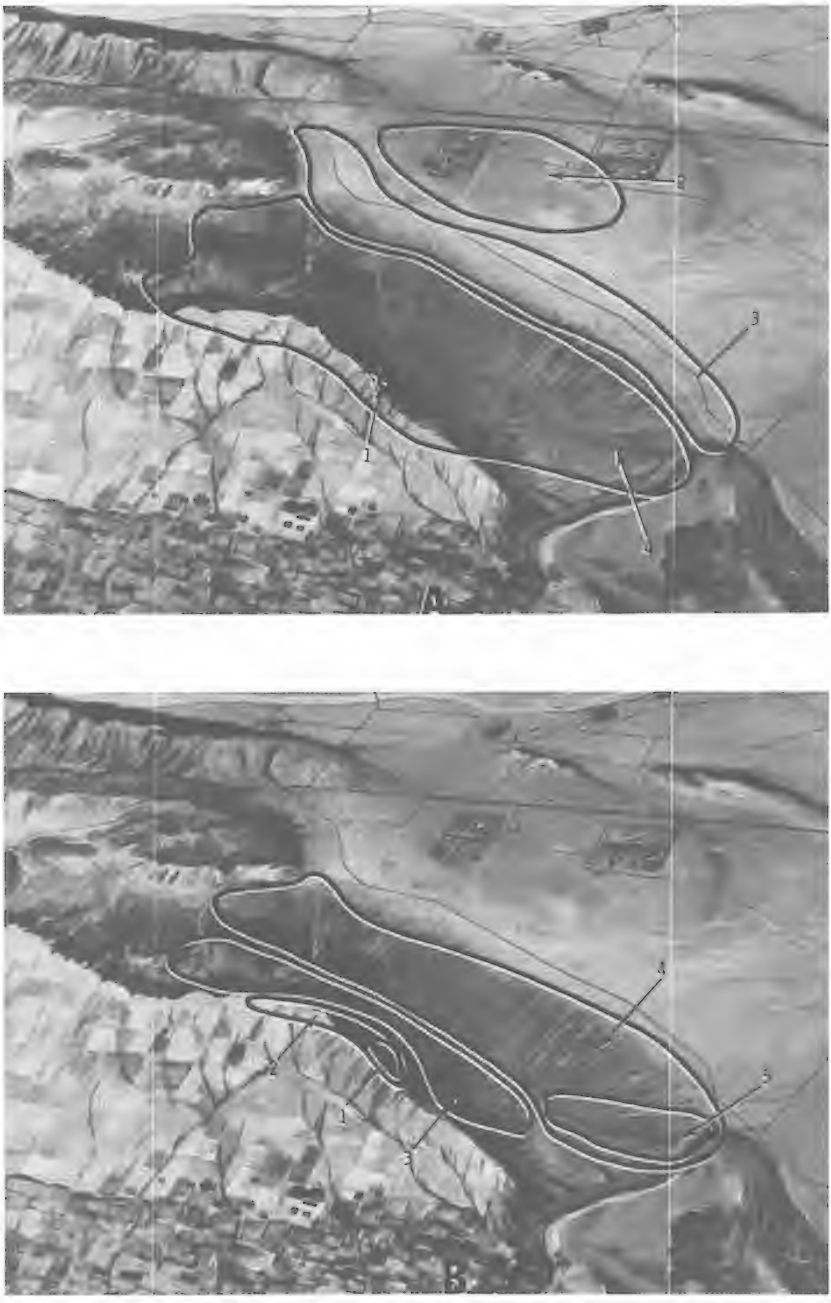

Figure 4. Results of cluster analysis of all microclimatic variables combined. A. major clusters; B. higher elevation subgroups. Clusters and subgroups designated by number are referred to in the text.

precipitation (although not as a distinct 3-unit cluster except for precipitation). Apparently, the edge effect of the valley confluence is very important in determining the close relationships of these sites, for they form the only cluster that lies perpendicular to isotherms, isohyets, and terrain contours.

The low elevation stations in the concave microtopography group (Fig. 4A) separate out as a cohesive cluster only in terms of minimum temperature; precipitation and maximum temperature patterns are not nearly as closely related for these stations. However, the fact that they group so solidly in the average (or combined) calculation indicates that minimum temperatures are of first importance in their microclimates, hence their label "frost pockets." These minimum temperature patterns are probably related in part to the temperature inversion which forms in the Cold Creek Valley nearly every night (Hinds and Thorp, 1971).

Exposed ridgetops on steep slopes (sites 16 and 17 at an elevation of 1100 m, see Fig. 1) never clustered with a comparable site on an exposed, but more moderately sloped, ridgetop a couple hundred meters lower in elevation (site 12, elevation 940 m). Causes of this lack of congruence remain obscure, but the distinction occurred throughout, in terms of both temperature and precipitation patterns. Possibly wind differences alter precipitation and temperature patterns: the higher elevation sites have a stony lithosol with little fine material, indicating extreme wind removal rates, in contrast to the lower site (12), which has a relatively deep loessal soil. Certainly the vegetation is different: site 12 supports a dense stand of cheatgrass (*Bromus tectorum*) and a few shrubs (*Artemisia tridentata* and *Chrysothamnus nauseosus*), while the higher sites, 16 and 17, support cushion plants, such as *Phlox hoodii* and *Happlopappus stenophyllus,* and small grasses (*Poa sandbergii*). The cluster analysis suggests the vegetation change is correlated with a change in climatic patterns as well as the obvious change in substrate.

A different problem is illustrated by the large cluster at mid-to-low elevations in Figure 4B:4, which includes nine sites at elevations ranging from 200 to 500 m. This cluster is well removed from strong topographic influences, relatively uniform in appearance, and not affected by steep slopes or excessive exposure to wind or insolation. The vegetation tells a different story, however, because an ecotone, between communities with and without *Agropyron spicatum,* lies at an elevation of about 300 m, right through the heart of this large cluster. We think this occurrence reflects a missing element in our analysis, probably some measure of magnitude in the microclimatic measurements (although edaphic influences are certainly possible). Our clusters were based upon correlation coefficients, which reflect patterns much more sensitively than amounts. The ecotone involving *Agropyron* correlates with increasing precipitation and warmer night temperatures that accompany increasing elevation in this area (Hinds and Thorp, 1971), whereas patterns as determined by our cluster analysis are very similar.

Our analyses have clearly shown that patterns of temperature and precipitation may produce significantly different microclimatic patterns. Two extensions of this work seem desirable. First, some way of including relative or absolute magnitudes of microclimatic factors must be found; and second, to relate microclimates to the landscape, we need to sample vegetation quantitatively in the immediate vicinity of our stations, then attempt to relate plant community structure to the various microclimatic variables or clusters we have been measuring. Such relationships should provide insights into how varied weather patterns, that is, environmental heterogeneity, affect floral species presence and abundance.

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Association News

The annual meeting of the Association was held at Eastern Washington State College on March 25, 26, and 27. There were about 450 registered for the meeting and 170 papers delivered at the various sections. A special symposium on Northwest ecology was very well received.

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Outstanding Scientist named was:

Walles T. Edmondson, Dept. of Zoology, University of Washington

Research Grants made were:

George R. Priest, Geology, Oregon State University, $270
Robert L. Lerner, Botany, University of Washington, $165
Stephen T. Lindsay, Biology, Walla Walla College, $140

The membership approved two constitutional changes. The first one clarified procedures for amending the constitution. The second one was to include a dissolution clause as required by the United States Internal Revenue Law.

The 1977 meeting of the Association will be held at Oregon College of Education in Monmouth on March 24, 25, and 26.

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Phenology of Steppe Plants in Wet and Dry Years

Abstract

In the arid *Artemisia tridentata-Agropyron spicatum* plant community of south-central Washington, precipitation in the 1973-74 season (October 1 to September 30) was 2.78 times that in the 1972-73 season. Nine of 12 plant species flowered later and longer in the 1973-74 season than in the 1972-73 season, even though temperatures during the flowering period of the two years were similar. These data suggest that the greater soil water content of the 1973-74 season caused the prolonged and delayed phenological development. The species not responding to the added precipitation and soil moisture in 1973-74 had growth restricted to the cool, wet months of late winter and early spring. It appears that early growing species, although unable to take advantage of added precipitation, have a stable habitat. In contrast, warm-season species can use the additional water of a wet year, but risk drought in years of low precipitation.

Introduction

In general, phenology is the study of the relationship between developmental state and environment. Ecosystem dynamics, both within and between trophic levels, depend in large part on the timing of plant developmental stages. For example, reproductive success in pronghorn is directly related to the developmental state of the food plants (Ellis, 1970).

The undisturbed Arid Lands Ecology (ALE) Reserve on the Energy Research and Development Administration's Hanford Reservation in south-central Washington offers the opportunity to study steppe plants in an environment not grazed by livestock. The drought of the 1972-73 season (October 1 to September 30) and abundant precipitation of the 1973-74 season presented the opportunity to compare the phenological response of native species on the ALE Reserve to these contrasting weather conditions. The purpose of this paper is to show the phenological response of 12 native species to the contrasting water availability of the 1972-73 and 1973-74 seasons. The effect of temperature on phenological change is also considered, but a detailed analysis of the effect of temperature on phenological change is not the purpose of this paper.

Phenological change has been correlated with insolation and average daily air temperature (Caprio, 1971), cumulative sums of degree hours (Lindsey and Newman, 1956; Jackson, 1966), moving averages of maximum and mean temperatures (Sauer, 1975), increasing air temperatures and insolation in spring (Ratcliff, 1961), photoperiod and rainfall pattern (Tothill, 1966), period of heaviest precipitation (Burk, 1966), soil temperature (Holway and Ward, 1965) and patterns of temperature and rainfall (Mueggler, 1972; Blaisdel, 1958).

Methods

All observations were made on the US/IBP Grasslands Biome ungrazed study area (ele-

vation 365 m) on the ALE Reserve in south-central Washington. This area is of uniform slope, exposure, vegetation, and soil (Rickard *et al.,* 1975) and is in the *Artemisia tridentata-Agropyron spicatum* association of Daubenmire (1970).

Ten plots each 15 m x 15 m were set out in March 1973. In each plot one individual of all plant species present was marked with a small flag. Periodically the phenological stage (Table 1) of each flagged individual was recorded. Length of time between observations varied from one week, when plants were rapidly changing in spring and summer, to monthly during fall and winter.

TABLE 1. The six phenophases used to describe developmental state.

1.	Begin Growth
2.	Begin Reproduction (floral buds appear)
3.	Begin Flowering
4.	End Flowering
5.	End Reproduction (all seeds ready for dispersal)
6.	End Growth

In August 1973, a wildfire burned the phenology plots. To continue the observations on comparable vegetation, another 10 plots were established approximately 200 m away in a very similar unburned area with the same experimental design and procedures.

Plant nomenclature is that of Hitchcock and Cronquist (1973).

Soil water content was gravimetrically sampled at 10 cm depth increments within 25 m of the phenology plots. Air temperatures, at 1 m height, were taken approximately 20 meters in 1972-73 and 100 meters in 1973-74 from the phenology plots, and reduced to monthly averages of maximum and minimum. The abiotic data were taken from the meteorological network located on ALE. Soil water data were collected in connection with the US/IBP Grasslands Biome study.

These data are presented for the period October 1 to September 30 for each year. In this region, growth starts with the first soaking rains in fall, then stops with low winter temperatures. In spring, rising temperatures accompany a burst of growth, which ceases with summer drought and heat.

Results and Discussion

Precipitation in the wet 1973-74 growing season was 37.5 cm, considerably more than the 13.5 cm that fell during the dry 1972-73 growing season. Nearly all precipitation fell in the fall and winter months (October to March). Clearly, higher soil water contents and deeper percolation occurred during the 1973-4 season (Table 2). In 1972-73 precipitation percolated to approximately 60 cm, but in 1973-74 the soil was wetted to a depth of 180 cm. During July, 1973, soil water content was below 6 percent, the approximate soil water content for –15 bars soil water potential, at all soil depths, but in July, 1974, all strata but two were above 6 percent soil water content. Deep rooted species or species with the capacity to grow roots deep into the soil therefore had a reservoir of soil water well into summer. It should be noted that biomass continued to accumulate after soil water content decreased below 6 percent indicating that the –15 bar value is not the lower limit of soil water potential for water uptake (Cline *et al.,* 1975).

TABLE 2. Percent soil water at two dates in the growing season to illustrate the greater soil water content in the 1973-74 season. Soil water content at –15 bars soil water potential is approximately 6 percent.

Depth dm	Feb. 16, 1973	Feb. 6, 1974	July 27, 1973	July 31, 1974
0-1	18.1	13.4	1.7	3.0
1-2	14.6	14.6	2.8	4.8
2-3	12.9	16.2	4.2	6.1
3-4	12.7	18.6	5.0	6.6
4-5	12.1	19.1	5.4	6.9
5-6	9.1	19.3	5.2	7.1
6-7	7.6	17.7	4.4	6.2
7-8	5.0	17.6	4.0	6.0
8-9	4.4	16.3	4.0	6.0
9-10	4.2	14.8	4.0	6.0
10-11		12.0		6.5
11-12		9.5		7.0
12-13		6.2		7.5
13-14		4.2		8.0
14-15		4.5		8.1
15-16				8.1
16-17				7.2
17-18				6.3

Maximum air temperatures (Table 3) in March and April and minimum winter temperatures were slightly higher in 1973-74 than the previous season.

TABLE 3. Monthly average temperatures (C°) illustrating the slightly warmer 1973-74 season.

	Maximum Air Temperatures		Minimum Air Temperatures	
	1972-73	1973-74	1972-73	1973-74
October	22.2	27.8*	10.0	14.5*
November	18.4	*	7.6	*
December	6.4	15.6	1.4	8.2
January	2.8	*	–1.7	*
February	2.3	11.1*	–4.3	4.9*
March	6.3	10.0	–.4	3.4
April	12.3	14.4*	2.4	4.9*
May	17.4	17.2	4.5	7.2
June	23.7	21.6	9.4	9.4
July	26.7	32.1	12.1	15.8
August	33.5	33.3	17.3	16.9
September	30.6	34.0	15.0	18.9

* Indicates more than 10 days of data missing from that month due to instrument failure.

Phenological progression through the 1972-73 and 1973-74 seasons for 12 prominent species in shown in Figure 1. These species vary in growth form from a woody shrub (*Artemisia tridentata* Nutt.) to small shrubs less than 30 cm in height (*Erigeron filifolius* Nutt. and *Phlox longifolia* Nutt.) to a decumbent, semi-woody perennial in direct contact with the soil surface (*Antennaria dimorpha* (Nutt.) T. & G.) to perennial bunchgrasses (*Agropyron spicatum* (Pursh) Scribn. and Smith, *Poa sandbergii* Vasey, *P. cusickii* Vasey, *Stipa thurberiana* Piper) to suffrutescent perennials (*Lupinus laxiflorus* Dougl. *Lomatium macrocarpum* (Nutt.) Coult. and Rose, *Crepis atrabarba* Heller

ex Lindl., to a bulb (*Calochortus macrocarpus* Dougl.). A phenophase is indicated on Figure 1 when one or more of the tagged individuals were in that phenophase, except in the case of dead or dormant leaves which were recorded when all individuals were in that state.

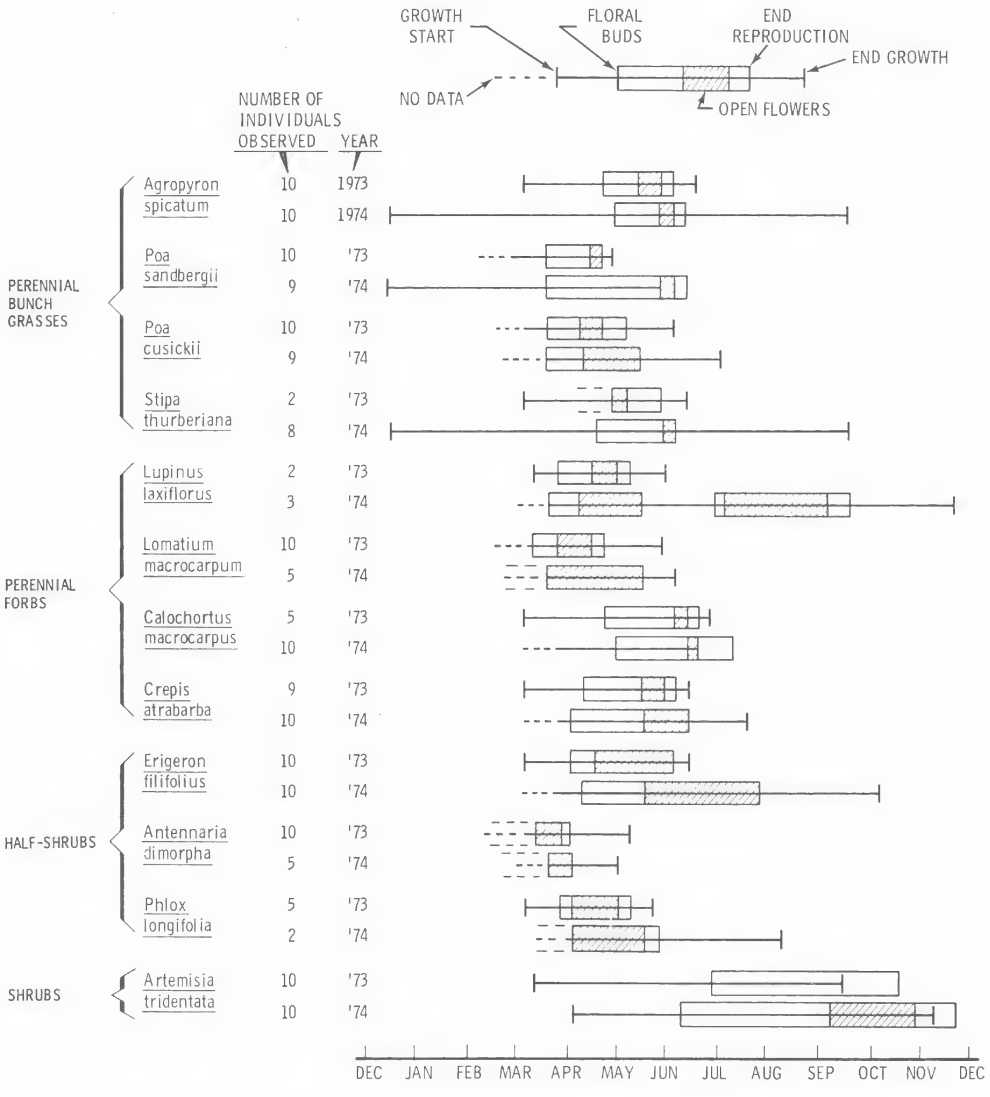

Figure 1. Phenological state of 12 species through the 1972-73 and 1973-74 growing seasons, and the number of individuals of each species observed.

These twelve species differed in phenophase development betwen the two years, but to different degrees. The least different was *Antennaria dimorpha,* one of the first species to flower in the spring and complete its growth cycle. Most differences occurred for species which normally continue growth during the warm and dry weather. The additional soil water available in 1974 apparently permitted many of the later growing species to continue to grow and even flower through the summer. *Agropyron spicatum* and *Stipa thurberiana* remained green, at least to a limited degree, through the 1974 summer, but were dormant by mid-summer in 1973. All individuals of *Erigeron filifolius* continued to grow vegetatively and in some cases flower and set seed through the 1974 summer in sharp contrast to the early summer onset of dormancy in 1973. *Lupinus laxiflorus* grew through the 1974 summer and had two flowering and growth periods. The first period was associated with larger individuals, presumably older plants, and the second period was associated with smaller individuals, possibly plants that germinated during the fall of 1973.

Several species (*Poa sandbergii, P. cusickii, Erigeron filifolius, Stipa thurberiana, Calochortus macrocarpus, Artemisia tridentata, Lomatium macrocarpum, Crepis atrabarba,* and *Phlox longifolia*) flowered later and longer in 1973-74 than in 1972-73. Later flowering has been associated with lower temperatures (Sauer, 1975; Harris and Scott, 1969; Stanfield, Ormrod, and Fletcher, 1966; Blaisdel, 1958). However, 1974 was slightly warmer than 1973, suggesting that soil water content also regulates phenological change and that the extended period of phenological progression is a result of the extended period of available soil water in 1974. Perhaps these air temperature data are not adequate to describe the temperature environment of these plants. The temperature of the soil surface, particularly on a clear day, would be higher than the air temperature at 1 m, and those plants on or near the soil surface would experience higher temperatures than those above the soil surface. The first species to flower, *Antennaria dimorpha,* is a low growing plant that remains in contact with the soil surface.

Agropyron spicatum and *Stipa thurberiana* resumed growth earlier in 1973-74 than in 1972-73. The January-March period of 1973 was colder than the same period of 1974, suggesting that the earlier growth of these two bunchgrasses in 1974 was a result of the warmer winter temperatures. In 1962, *Agropyron spicatum* had initiated growth by October 6 in many plant communities of eastern Washington, including the *Artemisia tridentata-Agropyron spicatum* community type on the ALE Reserve (Daubenmire, 1970). The nearly 2.5 month difference in growth initiation between 1974 and 1962 can be traced to the presence of soil water at greater than –15 bars soil water potential, a minimum of 2.5 months earlier in Daubenmire's 1962 study area (Daubenmire, 1972) than on the ALE 1973-74 study sites. An additional response in some species to the increased soil water reserves of 1973-74 was abundant flowering and seed set, particularly in *Artemisia tridentata* and *Calochortus macrocarpus.*

A problem encountered in this study was delimiting in time the beginning and end of each phenophase. The initiation of growth in the bunchgrasses was obscured by dead stems. Those species with leaves present year around presented particular problems. *Artemisia tridentata* and *Erigerion filifolius* displayed no clear start and stop of growth, as by bud burst or leaf drop. Perhaps these species only stopped growing and remained capable of growing at any time of the year when temperature and water conditions were simultaneously adequate for growth. Summer temperatures may stop growth, even when water is available. Growth then would be resumed in the fall with the return of

moderate temperatures and continue until low winter temperatures again stopped growth. These hypotheses should be tested experimentally.

It is tempting to speculate that the early growing species have a different evolutionary strategy than late growing species. In late winter and early spring, the upper soil layers (top 30 cm, for example) are usually wet and soil water content nonlimiting to growth. While air temperatures are low, soil surface temperatures are higher and adequate for growth of those species adjacent to the soil surface. These early growing species have evolved an early growth to avoid drought even in years of low rainfall when only the top soil layers are wetted. For this dependability of habitat, these species pay the price of being unable to take advantage of above average rainfall. Those species that grow later in the season risk the possibility of poor growth and seed production, but have the capacity to take advantage of above average rainfall. Further speculating, if there should be a period of several years of above average rainfall, the late growing species would increase at the expense of the early growing species. On the other hand, a long series of dry years would favor the early growing species.

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Exposure, Clearcutting, and Burning Affect Soil Moisture Levels

Abstract

The water content of soils increases when a forest is clearcut and the slash is burned. The amount of increase depends on the exposure of the site. These conclusions are based on a new interpretation and reanalysis of the 13-year soil moisture phase of the Wagon Wheel Gap experiment.

The Wagon Wheel Gap experiment in Colorado (1) was the first controlled watershed management experiment. Its specific goal was to determine "the effects of the forest destruction upon the time and amount of streamflow" in the central Rocky Mountains. The 15-year experiment was conducted on two areas (A—unlogged, B—clearcut and burned after a preliminary calibration period), and resulted in a published report that provides a wealth of data.

One phase of the study was an investigation of soil moisture levels before and after logging. Upon completion of the experiment, the investigators noted that "the natural variation of soil texture at the different stations will account for the entirely different moisture content . . ." and "Because of these soil variations station to station comparisons are not permissible." Bates and Henry (1) concluded that "No definite conclusion can be drawn" on the effect of forest removal on soil moisture levels; but they also qualified this conclusion by noting that "if the forest removal did decrease the summer drain upon the soil moisture, the difference must have been very slight."

I have reanalyzed the soil moisture data tabulated in the final Wagon Wheel Gap report (1) and concluded that logging and burning substantially altered soil moisture levels. This conclusion is consistent with the results of more recent investigations (2, 3, and 4).

A New Interpretation

The Wagon Wheel Gap report provides soil moisture data for the summer months (June-September) of 1914-1926. The data, collected weekly, are tabulated by soil depth (one, two, and three feet), by plots (north and south slopes of areas A and B), month, year, and period: pre-denudation (1914-1919) and post-denudation (1920-1926). Although the designations pre- and post-denudation are correct, they are nevertheless misleading with respect to the soil moisture study.

A close study of the report reveals the following sequence of events. At the beginning of the experiment (1913) the investigators excavated four soil pits in areas A and B, cleared the pits of rocks, and then (to facilitate later sampling with an auger) refilled them with native, rock-free soil. Six years later (summer 1919) they clearcut area B and piled the slash in windrows spaced 30 feet apart, and the following year (September 1920), they burned the slash. In effect, the soil moisture phase of the

experiment consisted of two treatments: An initial treatment that eliminated all root activity in all four plots, and a second treatment (six years later) imposed on only the two plots in area B. Ostensibly, the second treatment reinforced the first by again eliminating root activity. As a consequence of these treatments, we should expect two results:

(1) Soil moisture levels at all plots should decrease gradually during the first six years because roots of plants surrounding the soil pits should gradually invade the root-free soil and extract water for transpiration;

(2) During the second period (the "post-denudation" period) soil moisture levels in the unlogged areas should continue their downward trend because of the continued proliferation of roots; but in the logged and burned areas the downward trend should be interrupted.

Soil Moisture as a Time Series

If the above reasoning is correct, and the entire elapsed time of the experiment is considered as a simple time series, then the slope of the soil moisture line should be negative (*i.e.,* downward with the passage of time) for the unlogged plots (area A); but in the logged plots (area B) the slope should be less negative or even positive if the soils are exposed to additional sources of water. These conclusions should be apparent only if approximately equal amounts of precipitation characterized the two periods.

Thus, the first question to be answered is whether precipitation levels were approximately equal in both watersheds during the two periods. Analysis by Student's "t" test (5) of summer precipitation data for the 13 years for which soil moisture data are available reveals no significant difference between either areas or periods:

	Area A	Area B	"t"
	Summer precipitation (inches)		
Pre-denudation period	2.15	2.19	0.09
Post-denudation period	2.02	1.98	0.11
"t"	0.39	0.59	

On the other hand, despite the equality of measured precipitation, large differences are apparent among the soil moisture regression coefficients for the 13-year time series —differences that reflect the effects of both exposure and treatment. Regression coefficients for the linear trend of soil moisture over time for the four plots are tabulated below. Each of the listed coefficients is the average of 12 coefficients (four months, three depths) which characterize a 13-year soil moisture trend. The regression coefficients reveal that for the June-September months at Wagon Wheel Gap, soils on south slopes lose water at a slower rate than on north slopes, and also that the two treatments on area B (in contrast to only one on A) resulted in a significant gain in soil moisture—*i.e.,* less negative slopes. (** represents the 1-percent level of significance.)

	N-exposure	*S-exposure*	*"t"*
	Regression coefficients		
Area A	--0.69	–0.19	5.39**
Area B	–0.40	+0.27	10.13**
"t"	3.02**	7.47**	

Actual and Expected Soil Moisture Levels

A legitimate assumption is that during the six-year first phase of the experiment, the roots of plants surrounding the soil plots gradually encroached into the initially root-free soil. Another reasonable assumption is that root proliferation in the unlogged soil sites continued unabated during the second period. If these assumptions are correct then in the unlogged sites (area A) soil moisture content during the second period should be less than the amount predicted on the basis of soil moisture-precipitation regression equations developed for the first period. In contrast, in the logged sites (area B), root development should be less rapid during the second period, and more water should become available because of reduced interception of summer rains. During the second period, soil moisture conditions in the logged sites should differ considerably from those in the unlogged sites. This conclusion is corroborated in the following tabulation of differences between actual and predicted values (percent of dry weight) of soil moisture content during the post-denudation period. Predicted values are based on soil moisture-precipitation equations that characterized the pre-denudation period. Analysis by Student's "t" shows that the twice-treated B plots gained water relative to the once-treated A plots, and also that the second treatment was particularly effective on south slopes. (* and ** indicate the 5- and 1-percent levels of significance.)

	N-exposure	*S-exposure*	*"t"*
	(soil moisture change: actual %—predicted %)		
Area A	–1.86	–0.50	4.99**
Area B	–1.03	+1.22	10.71**
Student's "t"	2.55*	14.88**	

Covariance Analysis

Additional proof of the effect of clearcutting and burning on soil moisture levels can be obtained by covariance analysis—a technique used to analyze the relations between variables that are initially unlike.

The Wagon Wheel Gap experiment comprised two periods and four plots. I shall designate plots on north and south exposures in areas A and B as A_N, A_S, B_N, B_S. All plots were treated at the beginning of the experiment, but only two plots (B_N,B_S) were again treated at the beginning of the second period. The change in relation between any two plots during the two periods should depend on the effectiveness of the treatment imposed during the second period. Thus, if the second treatment affected soil moisture levels, then the relation that existed between B_S and A_S during the first period should change during the second; similarly, the relation between B_N and A_N should also change; moreover, if the effectiveness of the treatment depended on ex-

posure, then the relation between B_N and B_S should also change between periods, but in the unlogged area the relation between A_N and A_S should remain constant. Statistical evidence for the change in relations induced by the clearcutting and burning treatment is shown in the following tabulation in which only the 5 percent (*) and 1 percent (**) levels of significance are indicated. Relations between A_N and A_S during the two periods remained constant and therefore are not listed. On the other hand, significant changes did occur in the relations between B_N and B_S. The tabulation shows that logging and burning altered soil moisture levels and that the magnitude of the effect depends on the exposure.

Soil depth		*Comparison*	
feet	B_N/B_S	B_S/A_S	B_N/A_N
		JUNE	
1	**	**	—
2	*	—	*
3	—	—	**
		JULY	
1	**	**	*
2	**	**	*
3	**	*	
		AUGUST	
1	*	*	—
2	*	*	—
3	**	**	—
		SEPTEMBER	
1	*	—	—
2	**	**	—
3	—	*	—

Effect of Exposure

Soil moisture is greatly influenced by exposure, particularly in mountainous terrain, where snow is a major component of annual precipitation. South slopes receive more solar radiation than north slopes; their soils are warmer, shallower, and are also exposed to drying conditions for longer periods of time. Bates and Henry's report (1) documents significant differences between north and south slopes at Wagon Wheel Gap: Snow disappears from south slopes about five to six weeks sooner; average soil tempearture at the 12-inch depth is about 8°F (4.4°C) warmer; and the average summer soil water content is about 7 percent (of dry weight) lower. On the other hand, soils on northerly exposures at Wagon Wheel Gap appear to have a greater water holding capacity, and they also lose more water during the summer months, presumably because of greater transpiration. Vegetation is more dense on north slopes, and also establishes itself more quickly after logging and burning.

Effect of Burning

The effect of burning on soil moisture cannot be evaluated precisely because the experiment was not designed for this purpose. Nevertheless, a qualitative evaluation can be made. In their report, Bates and Henry (1) indicated that the up-and-down-hill windrows of slash covered 20 percent of area B and burned so intensely that mineral soil was laid bare and aspen roots were killed: "The most striking feature of the fire scars was the complete absence of aspen sprouts for several years after the windrows were burned, in contrast to the prompt and general appearance of aspen sprouts elsewhere." It is logical to surmise that at Wagon Wheel Gap slash burning not only delayed the reappearance of aspen, but also delayed potential water losses from transpiration, and consequently raised the general level of soil moisture.

Summary and Conclusion

A reanalysis of the soil moisture data of the Wagon Wheel Gap experiment shows that the water content of soils increases after a forest is clearcut and the slash is burned. These results become evident when the soil moisture phase of the experiment is reinterpreted in light of the actual conduct of the experiment. Initially, soil pits were dug, rocks sifted out, and native soil returned to the pits. The experiment therefore consisted of two treatments: an initial one that temporarily stopped all root activity in all plots; and a second treatment imposed six years later on only two plots. The experiment should be viewed as one that allowed roots to proliferate for 13 years in an initially root-free area, but temporarily impeded their growth in another area after six years of unimpeded growth. One would expect soil moisture to diminish gradually in the first area (because of increased root activity and transpiration losses), but to diminish at an overall reduced rate in the second area. The data corroborate these expectations and also reveal substantial differences between the effects of the treatment on soils located on north and south exposures. In the Wagon Wheel Gap area slash burning is significantly related to soil moisture because it prevents the prompt regeneration of aspen sprouts.

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Non-Forest Vegetation of the Central Western Cascade Mountains of Oregon

Abstract

Although non-forested areas in the Western Cascade Mountains of central Oregon are small in area, they are of floristic, ecological, and evolutionary importance. The wettest and driest communities succeed slowly, or not at all, to forest; but long-term maintenance of mesic meadows below timberline must be attributed to continued disturbance by frost, rodents, fires, and mass wasting. In order of decreasing moisture availability, the 12 communities described are: *Caltha/Carex/Dodecatheon* Bog; *Mimulus/Lewisia/Allium* Seep; *Veratrum/Valeriana/Senecio* Wet Meadow; *Orogenia/Dicentra/Erythronium* Snowbed; *Sambucus/Cardamine/Campanula* Talus; *Rubus/Pteridium* Meadow; *Bromus/Rudbeckia* Meadow; *Selaginella/Saxifraga/Penstemon* Cliff-face; *Gilia/Polygonum/Eriogonum* Lithosolic Meadow; *Quercus/Rhus/Bromus* "Savanna"; *Eriophyllum/Castilleja/Sedum* Lithosol; *Lotus/Chrysothamnus/Allium* Tuffaceous Gravel. More than 200 vascular plant species are assigned to the communities of which they are characteristic members.

Introduction

About 95 percent of the Western Cascade Province of Oregon is covered by coniferous forest. These forests have been the subject of much research effort, especially through the International Biological Program, and their basic vegetation patterns are now understood (Franklin and Dyrness, 1969; Dyrness, Franklin, and Moir, 1974; Hawk and Zobel 1974[1]). The remaining unforested portion of the Western Cascades is small in area, but the diverse habitats comprising it support 85 percent of the large Western Cascade flora, including many disjunct and endemic species of ecological and evolutionary interest. Non-forest areas are of different sizes and are variously isolated from one another. They thus offer insight into principles of dispersal, establishment, and competition in areas where living space is limited and divided among many species along steep environmental gradients. Historically, these rich sites have been ignored by researchers, but there is now a growing body of literature concerning them (Detling, 1953, 1968; Hickman, 1968, 1970, 1971, 1974, 1975, in preparation; Hickman and Pitelka, 1975). This report presents a preliminary classification of the non-forest communities of the region to facilitate further studies within the Western Cascades and to allow comparisons with the non-forest vegetation of other areas of the Pacific Northwest (Van Vechten, 1960; Archer, 1963; Horn, 1968; Kuramoto, 1968; Franklin and Dyrness, 1969).

The study area is bounded approximately by latitudes N 43° 30′ and N 44° 45′ and by longitudes W 122° and W 122° 30′. The region is characterized geologically by nearly horizontal flows of andesites and basalts that have been locally faulted and intruded. Oligocene and Miocene flows have been gently warped, but the Pliocene rocks that comprise many of the peaks have retained essentially their original attitudes.

[1] Reference added in proof: Zobel, D. B., A. McKee, G. M. Hawk, and C. T. Dyrness. 1976. Relationship of environment to composition, structure, and diversity of forest communities of the Central Western Cascades of Oregon. Ecol. Monog. 46: 135-56.

Erosion has produced a maturely dissected topography of valleys and steep ridges, the peaks of which stand at a height of 1600 to 1750 m. Numerous small Pleistocene glaciers were important in the erosion of the Western Cascades. Steep cirque headwalls with associated tarns occur on a number of peaks within the study area, especially on northern or eastern slopes. Erosional remnants such as dikes and plugs further diversify topographic surfaces.

July maximum temperatures average 27° C, and average annual precipitation ranges from 1500 to over 2000 mm (Franklin and Dyrness, 1969). Spring rainfall may be considerable and extend through June in unusually wet years, but little or no precipitation falls during July and August. Snowpack may reach 4 m, but is blown away from non-forested ridges and melts early in non-forested depressions. For most non-forest species, growing seasons are bounded by snowmelt (late May to mid-June) and by drying of the soil (early August to mid-September). In the wettest habitats, growth may continue until first snow (usually in early October), but is normally cut short by earlier frosts.

Succession toward climatic climax forest types is very slow in both the wettest and driest communities. In places they have persisted for more than 1000 years and can be considered topo-edaphic climaxes (Hickman, 1968). Boundaries between mesic meadows and forest are much more dynamic, with considerable invasion by trees. The precise interplay of factors responsible for the long-term maintenance of the mesic meadows is not clear, but the factors doubtless include fire; heavy snowpack; occasional snow- and landslides; rapid downslope creep of light loamy soils, especially in the spring; and the churning and cutting action of rodents, particularly *Aplodontia rufa.* Meadows may have been enlarged and modified by sheep grazing and related fires early in this century, but it was their previous existence that made grazing profitable. Comparison of current meadow boundaries with photographs from 1933 provides examples of forest encroachment on slopes that were severely burned between 50 and 100 years ago. It also demonstrates marked stability of other forest/meadow boundaries, indicating complex successional relationships.

All communities described here, even the mesic meadows, are reasonably longevous. Disturbed open habitats of little persistence such as roadsides, clearcuts, and regenerating burns are not included.

Methods

The 12 communities characterized below were isolated using reconnaissance sampling data from more than 40 peaks within the study area. Data were compiled during nine growing seasons over an 11-year period from 1965 to 1975. Occurrence and relative abundance of vascular plant species were recorded from each obviously distinct habitat that could be isolated on each peak. Communities chosen for description are those that recur widely in the area, often wherever certain physical conformations are found. Intergradation of associations does occur, especially in the drier meadow and lithosolic types. In spite of local intergradation, the communities are considered independent vegetation units for three reasons: 1) in some areas they do not intergrade; 2) they indicate different physical environments and different modes of adaptation; and 3) together they encompass a great diversity of species.

Scholander pressure chamber measurements of xylem sap potential in 11 of the

communities (Hickman, 1968, 1970) provided a basis for arraying the communities by available moisture. Presence of species in two or more communities aided in integrating the measures.

In 1971, extensive random quadrat sampling of a restricted area was undertaken prior to analysis of environmental gradients and construction of a vegetation map. Computer analysis supported delimitation of the six associations included in those samples, all of which were originally recognized from semi-quantitative reconnaisance techniques. Those data and the vegetation map will be published separately.

Following Daubenmire (1968), the term "community" is used here in a general sense. "Associations" are stable communities near climax, and "associes" are communities that generally succeed to forest, and so are less stable.

Nomenclature follows Hitchcock and Cronquist (1973), except where authorities are given. Voucher specimens for all species are on file at Swarthmore College.

Results and Discussion

Franklin and Dyrness (1969) have divided the Western Cascades at this latitude into three Forest Zones. The *Tsuga heterophylla* Zone extends to a maximum elevation of 1000 m. It corresponds with the Humid Transition Zone of Merriam (1890) and the lower wet montane forest of Holdridge (1967). One non-forest association is confined to this zone. The middle elevation *Abies amabilis* Zone (representing Merriam's Canadian Zone and Holdridge's upper wet montane forest) predominates in the Western Cascades, but the lower *Tsuga mertensiana* Zone (Hudsonian Zone; upper wet montane forest) is also present above 1500 m on some of the higher peaks. The last two zones are not distinguishable on the basis of non-forest communities in the Western Cascades, but together support the remaining 11 communities described here. All Western Cascade peaks are below climatically determined timberline.

Figure 1 arrays the communities along axes representing substrate texture and soil moisture during the blooming and fruiting seasons. The *Quercus/Rhus/Bromus* community is restricted to the *Tsuga heterophylla* Zone. Seven comprise a major trend of decreasing moisture availability within the *Abies amabilis* and *Tsuga mertensiana* Zones. The remaining four (*Mimulus/Lewisia/Allium; Orogenia/Dicentra/Erythronium; Sambucus/Cardamine/Campanula;* and *Selaginella/Saxifraga/Penstemon*) occupy specialized habitats in the *Abies amabilis* and *Tsuga mertensiana* Zones and are described last.

Table 1 summarizes the development of the 12 communities on 29 Western Cascade peaks. The peaks are listed in order from north to south. While most communities are distributed throughout the area, one is found primarily in the south (*Quercus/Rhus/Bromus*), and two are best developed in the north (*Veratrum/Valeriana/Senecio* and *Bromus/Rudbeckia*). Descriptions and brief discussions of the communities follow.

Quercus garryana/Rhus diversiloba/Bromus mollis "Savanna" Association

On south-facing slopes at intermediate elevation in the *Tsuga heterophylla* Zone (and in the study area especially in the region of the South Fork of the McKenzie River), dry clearings and meadows contain a large number of species characteristic of the hills and fields within the Willamette Valley and other major valleys in western Oregon. This savanna-like association is not found above 600 m (except on Castle Rock, where it reaches 1150 m) and is therefore restricted to peaks with low elevation south-facing slopes. Such areas support scattered trees of *Quercus garryana, Arbutus menziesii,*

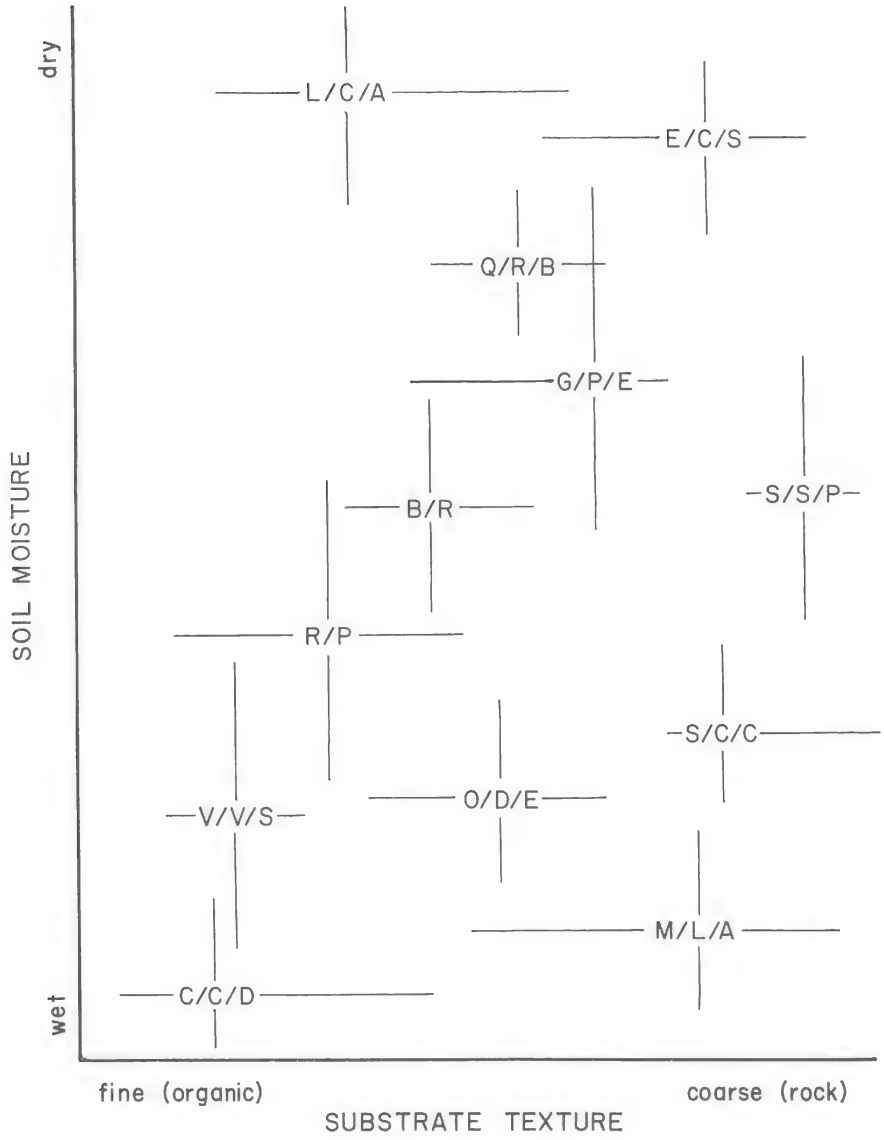

Figure 1. Substrate texture and soil moisture in 12 Western Cascade non-forest communities. Soil moisture extrapolated from maximum reproductive-season sap potentials; substrate texture from estimated average particle size, including the boulder fraction. Vertical and horizontal lines approximate the range of the two parameters encountered in the field, and suggest the degree of overlap among communities. B/R = Bromus carinatus/Rudbeckia occidentalis Meadow; C/C/D = Caltha biflora/Carex sitchensis/Dodecatheon jeffreyi Bog; E/C/S = Eriophyllum lanatum/Castilleja hispida/Sedum oregonense Lithosol; G/P/E = Gilia aggregata/Polygonum douglasii/Eriogonum nudum Lithosolic Meadow; L/C/A = Lotus nevadensis douglasii/Chrysothamnus nauseosus albicaulis/Allium crenulatum Tuffaceous Gravel; M/L/A = Mimulus guttatus/Lewisia triphylla/Allium amplectens Seep; O/D/E = Orogenia fusiformis/Dicentra uniflora/

TABLE 1. Development of 12 non-forest communities on 29 Western Cascade Mountain peaks. 1 = community present, but restricted in area or without full complement of diagnostic species; 2 = community moderately well developed, but not extensive; 3 = community fully and extensively developed. Peaks are listed from north to south.

	Quercus/Rhus/Bromus	Caltha/Carex/Dodecatheon	Veratrum/Valeriana/Senecio	Rubus/Pteridium	Bromus/Rudbeckia	Gilia/Polygonum/Eriogonum	Eriophyllum/Castilleja/Sedum	Lotus/Chrysothamnus/Allium	Mimulus/Lewisia/Allium	Orogenia/Dicentra/Erythronium	Sambucus/Cardamine/Campanula	Selaginella/Saxifraga/Penstemon
Monument Peak		1		2	1		2			1	1	1
Bachelor Mt.		1	2	2	2	2	2		1	2		1
Three Pyramids			1	2	2		2				1	3
Crescent Mt.			1	3	2		2			1		
Echo Peak		2	2	3	3	3	3	1	1	2		2
South Peak		1	2	3	3	3	3	1	2	3		3
Cone Peak		2	3	3	3	3	3	3	3	3		3
Iron Mt.		1	2	3	3	3	3	3	3	3		3
Browder Ridge		1	2	3	2	3	3	1	3	2	1	2
Jumpoff Joe				2			1				3	1
Squaw Peak			2	2	1						3	
Twin Buttes			2	2	1	1	2				2	1
Carpenter Mt.			2	1	1	1			1	3	3	
Tidbits Mt.			1	1		1	3				3	2
Lookout Mt.			1	2			1				2	2
Frissell Pt.			1	1		1	2					
Castle Rock	2			1		1						
O'Leary Mt.			2	2		2	2					1
Horsepasture Mt.			2	3	2	3	2		1	2	1	1
English Mt.		2	2	1	1	1	1		1	1		
Lowder Mt.		3	3	2	3	1	3		1	2	1	
Tipsoo Butte	1			1		1	2				1	
Olallie Mt.			1	2	1	2	1		1	1		
Rebel Rock	3		1	3	3	3	3	1	2	2		
Indian Ridge		1	1	2			1		1	2		1
Sardine Butte		1		1	1		1				1	1
Huckleberry Mt.				1			1					
Fairview Peak		2		1		3	3		1	1	1	1
Bohemia Mt.	1	1	1	2		3	3	2	1	2	2	3

Erythronium grandiflorum Snowbed; Q/R/B = Quercus garryana/Rhus diversiloba/Bromus mollis "Savanna"; R/P = Rubus parviflorus/Pteridium aquilinum Meadow; S/C/C = Sambucus racemosa arborescens/Cardamine integrifolia sinuata/Campanula rotundifolia Talus; S/P/P = Selaginella wallacei/Saxifraga bronchialis vesperina/Penstemon rupicola Cliff-face; V/V/S = Veratrum viride/Valeriana sitchensis/Senecio triangularis Wet Meadow.

and *Philadelphus gordonianus,* and scattered shrubs of *Rhus diversiloba, Ceanothus sanguineus,* and *Ribes sanguineum.* Annuals are abundant and account for about 50 percent of the cover. Especially important are the grasses *Bromus mollis, B. tectorum, Cynosurus echinatus,* and *Aira caryophyllea,* and secondarily such annual forbs as *Polygonum spergulariaeforme, Clarkia rhomboidea, C. amoena lindleyi, Linanthus bicolor, Orthocarpus attenuatus, Githopsis specularioides, Conyza canadensis, Madia gracilis,* and *M. exigua.* The dominant perennial herbs include *Brodiaea hyacinthina, B. congesta, Berberis aquifolium, Psoralea physodes, Convolvulus nyctagineus,* and *Apocynum androsaemifolium.*

Bedrock in these habitats is always near the surface, and soils are thin stony loams. Steep slopes and recurrent past fires may be responsible for these conditions. There is no current sign of succession to a Douglas-fir-dominated dry forest. While, in the absence of further fires, this must be expected eventually to occur, the "savanna" association is reasonably long-lived, and may be maintained indefinitely by periodic fires.

Caltha biflora/Carex sitchensis/Dodecatheon jeffreyi Bog Association

Continually wet habitats of gentle or level slope where snowmelt or spring water saturates rich organic soils throughout the summer support a number of species characteristic of sphagnum bogs. True bogs are rare in the Western Cascade Province. A similar environment occurs on mats of *Carex sitchensis* and *C. aquatilis* surrounding small tarns above 1500 m. In addition to the nominate species, dominants include *Sphagnum* spp., *Deschampsia cespitosa, Ranunculus gormanii, Aster alpigenus, Pedicularis groenlandica, Tofieldia glutinosa brevistyla,* the shrubs *Vaccinium uliginosum* and *Lonicera utahensis,* and shrubs and small trees of *Salix geyeriana meleina* and *S. commutata.* Other important species are *Lycopodium sitchense, Equisetum arvense, Muhlenbergia filiformis, Carex luzulina, C. limosa, C. muricata, C. rostrata, Scirpus cespitosus, S. congdonii, Eleocharis pauciflora, Dulichium arundinaceum, Lysichitum americanum, Habenaria dilatata, H. saccata, Polygonum bistortoides, Spiraea densiflora, Trifolium longipes, Parnassia fimbriata, Drosera rotundifolia, D. anglica, D.* x *"obovata," Viola mackloskeyi, V. adunca, Hypericum anagalloides, Perideridia gairdneri, Sium suave, Kalmia microphylla, Menyanthes trifoliata, Lycopus uniflora, Mimulus moschatus, Galium trifidum pacificum,* and *Microseris borealis* Bong.

Within large and complex sphagnum bogs, such as Quaking Aspen Swamp, and among smaller bogs, several distinct phases of this association are evident. Detailed studies of the vegetation of Quaking Aspen Swamp will be published separately.

There is variation in the longevity of *Caltha/Carex/Dodecatheon communities.* Bog soils are not usually appropriate for colonization by the dominant Cascade conifers. In some sites, however, cold- and water-tolerant species such as *Picea engelmannii* and *Abies lasiocarpa* are encroaching. In large open areas heavy winter snow and ice frequently break and kill invading saplings and young trees. In such sites, the association is topo-edaphic climax.

Veratrum viride/Valeriana sitchensis/Senecio triangularis Wet Meadow Associes

Open areas, most frequently on east- or northwest-facing slopes, which have fairly constant sources of moisture and sufficiently gentle slopes to build up deep organic

soils, support a characteristic wet meadow community. Variants of this associes occur in the High Cascades of Oregon, North Cascades, and Olympic Mountains of Washington(*cf.* Franklin and Dyrness, 1969). Additional important species include *Polystichum andersonii, Luzula parviflora, Mitella breweri, Ribes bracteosum, Rubus spectabilis, Hypericum formosum scouleri, Viola glabella, Circaea alpina, Oplopanax horridum, Ligusticum grayi, Hydrophyllum tenuipes, H. fendleri albifrons,* and *Mertensia bella.*

Farther north, a variant of this community occupies large open expanses, even on south-facing slopes. In the Western Cascades, it tends to be a forest-edge community, and is even found fully developed, but sparser in cover, under canopies of *Alnus sinuata* thickets. It also occurs under relatively open stands of *Abies amabilis, Chamaecyparis nootkatensis*, and *Tsuga mertensiana* on north slopes.

In the fully exposed habitats of bogs, but higher and drier than the *Caltha/Carex/Dodecatheon* association, this community recurs with the first two dominants replaced, respectively, by *Veratrum californicum caudatum* (and fertile hybrids between it and *V. viride*) and by *Heracleum lanatum. Oplopanax horridum* and *Polystichum andersonii* are absent from this phase, but there is otherwise co-ocurrence of the characteristic species. As with the previous association, winter-kill of young trees makes this phase much more nearly non-forest climax than the normal forest-edge phase. The latter is quite susceptible to invasion by trees but retains its characteristics even under forest canopy.

Rubus parviflorus/Pteridium aquilinum Meadow Associes

Rubus/Pteridium meadows occupy moderately steep mountainsides of variable exposure, but are least common on north slopes. Soils are deep brown loams that retain an adequate supply of moisture for plant growth until late summer, when plants in drier patches desiccate. Most of the component species are herbaceous perennials which normally have time to set seed during the moist early summer, but vegetative reproduction is also important, especially in the dominants. These meadows support *Lilium washingtonianum, Polygonum phytolaccaefolium, Lathyrus nevadensis lanceolatus pilosellus, Vicia americana truncata, Epilobium angustifollium, Ligusticum grayi, Mertensia paniculata, Erigeron aliceae, Cirsium callilepis oregonense,* and occasional ephemeral annuals such as *Galium bifolium* and *Gayophytum humile,* which grow in the shade of the taller perennials.

Several species occur both in these meadows and in the surrounding forest-edges, which are drier than those occupied by the *Veratrum/Valeriana/Senecio* community. They include *Dicentra formosa, Ribes binominatum, R. viscosissimum, Holodiscus discolor, Amelanchier alnifolia semiintegrifolia, Lupinus latifolius, Angelica arguta, Polemonium carneum, Penstemon serrulatus, Achillea millefolium lanulosa,* and *Luina stricta.*

The *Rubus/Pteridium* meadow is an extremely widespread type in the Pacific Northwest, especially at lower elevations, with variants occurring in the Coast Ranges, Olympic Mountains, and North Cascades. This associes has likely expanded due to grazing at the expense of grass-dominated meadows such as the following *Bromus/Rudbeckia* associes, but no quantitative evidence on this issue exists. Of all the non-forest communities, this one shows the most dynamic relationships with the surrounding forests. While fire or other disturbance may enlarge the meadows, invasion by trees is common,

especially in recently burned areas. Even though forest/meadow boundaries are constantly in flux, many areas appear to be quite stable and are probably mantained by a combination of extensive rodent churning and seasonally extensive downslope movement of the light-textured loams, both of which interfere with tree establishment.

Bromus carinatus/Rudbeckia occidentalis Meadow Associes

A drier and higher elevation counterpart of the previous meadow type, this associes still includes some of the forage grasses that probably have been reduced in abundance by grazing. The current grass dominants (*Bromus carinatus, Elymus glaucus, Stipa occidentalis californica,* and sometimes *Melica spectabilis*) are not such good forage as the less commonly encountered fescues (*Festuca ovina, F. viridula, F. idahoensis*), which may once have been dominant. Soils are light and loamy, with included fragments of andesite, and are subject to churning both by rodents and by frost. This associes may include many of the species of the preceding and following communities, but is characterized by the presence of the perennial herbs *Carex pachystachya, Habenaria unalascensis, Rumex acetosella, Fragaria virginiana platypetala, Potentilla glandulosa, Linum perenne lewisii, Hackelia micrantha, Artemisia ludoviciana latiloba,* and *Agoseris grandiflora;* the annuals *Polygonum minimum, Gayophytum diffusum, Gilia capitata, Phacelia linearis, Collinsia parviflora,* and *Orthocarpus imbricatus;* and occasional individuals of the snowbed perennials *Erythronium grandiflorum, Lewisia triphylla, Dicentra uniflora,* and *Orogenia fusiformis.*

A well-defined phase of this meadow on yet drier soils is dominated by *Carex rossii* and *Viola nuttallii bakeri,* with *Calochortus subalpinus, Lupinus laxiflorus,* and *Cirsium callilepis oregonense.* Further data may indicate the desirability of proposing this as a distinct associes.

Probably because of its shallower, drier soils that are also subject to churning, this associes is less frequently invaded by trees than are *Rubus/Pteridium* meadows. Some areas, however, are being colonized by sparse young *Abies grandis, A. amabilis,* or *A. procera,* so this community is considered an associes.

Gilia aggregata/Polygonum douglasii/Eriogonum nudum Lithosolic Meadow Association

The driest of the meadow associations in the Western Cascades includes many disjunct species. Soils are usually derived from friable or scoriaceous parent material and are lithosolic with a loamy matrix. Most species can tolerate low xylem sap potential (Hickman, 1970). Those which cannot die back earlier in the summer than those in the moister meadow communities. Although there are many annuals, there are no truly ephemeral species in this association. Additional species include the annuals *Polygonum cascadense, Gayophytum diffusum, G. humile, Microsteris gracilis, Collomia linearis,* and *Navarretia divaricata;* and the perennial or biennial herbs *Calochortus subalpinus, Rumex acetosella, Cerastium arvense, Potentilla glandulosa, Lupinus laxiflorus, Phacelia heterophylla, Monardella odoratissima,* and *Aster ledophyllus.*

As in all the remaining associations, succession is negligibly slow here. Continuous erosion keeps soils thin and sterile, and water stress in late summer is too great to be tolerated by tree seedlings and saplings. Although the specific stabilizing mechanisms differ, this and all remaining associations can be considered topo-edaphic climax.

Eriophyllum lanatum/Castilleja hispida/Sedum oregonense Lithosolic Association

This association cannot be considered meadow because soil development is minimal. It occurs on steep south- or west-facing slopes where lithosols creep downslope, on sloping, weathered outcrops, and on flat ridgetops of deflation armor. Many species are able to establish in cracks of outcrops or in occasional small pockets of finer material. No annuals are characteristic, but those of the preceding association sometimes grow here as well. Other herbaceous or shrubby perennials are *Aspidotis densa, Cheilanthes gracillima, Juniperus communis montana, Poa cusickii, P. incurva, Zygadenus venenosus, Comandra umbellata, Eriogonum umbellatum, E. compositum, Arenaria capillaris americana, Silene douglasii, Delphinium menziensii pyramidale, Erysimum asperum, Sedum divergens, S. stenopetalum, Pachistima myrsinites, Lomatium martindalei, Sanicula graveolens, Arctostaphylos nevadensis, Phlox diffusa longistyla, Phacelia heterophylla, Penstemon procerus brachyanthus, Antennaria microphylla, Erigeron foliosus confinis, Haplopappus hallii, Senecio integerrimus exaltatus, Microseris nutans,* and *Hieracium scouleri.*

Lotus nevadensis douglasii/Chrysothamnus nauseosus albicaulis/Allium crenulatum Tuffaceous Gravel Association

In this association plants are characteristically super-dispersed with much intervening area of fine scoriaceous gravel derived from topographically resistant but deeply weathering fine breccias or tuffaceous volcanics. The gravelly surface layer, which creeps steadily downslope, covers a thin layer of loamy mineral soil. Weathered bedrock is usually no deeper than 10 cm. This association, the driest in the Western Cascades, is confined to gentle slopes and is most characteristic of the Iron Mountain-Echo Mountain ridge, which has an unusually high proportion of tuffaceous Pliocene volcanics. It is further characterized by the presence of *Ivesia gordonii, Trifolium productum, Penstemon deustus, Aster gormanii,* and *Crepis occidentalis,* all of which are disjunct species in the Western Cascades. In addition it may support low densities of species characteristic of the *Eriophyllum/Castilleja/Sedum* association.

Mimulus guttatus/Lewisia triphylla/Allium amplectens Seep Association

Occasionally snowmelt trickles over outcrops, especially on south- or west-facing slopes where the thin soils common to non-forest habitats have eroded away because of fires, frost action, and other factors. These habitats desiccate about midsummer, and plants found here tend to be ephemeral annuals or stoloniferous or cormose perennials with ephemeral above-ground parts. Such plants survive the dry late summer in dormant condition. Other prominent species include *Polygonum kelloggii, Montia parvifolia, Saxifraga integrifolia, S. occidentalis rufidula, Gayophytum humile, Linanthus harknessii, Romanzoffia sitchensis, Mimulus breweri,* and *M. moschatus.*

Individual communities are usually small, being restricted in size by outcrop and spring co-occurrence. Nevertheless, they recur widely and faithfully. Occasionally they are shaded by adjacent forest, but successful invasion by trees of the outcrop seeps themselves has not been observed.

Orogenia fusiformis/Dicentra uniflora/Erythronium grandiflorum Snowbed Association

Beneath north-facing outcrops on steep slopes, as well as in wind-protected sites of other exposure, snow accumulates in winter to depths which may exceed 8 m. Several species, primarily of alpine or boreal affinity, flower, rapidly set seed, and desiccate at the edge of these snowbanks as they melt. Besides the nominates, such species include *Claytonia lanceolata* and *Mertensia bella,* as well as less consistently snowbed species such as *Trillium ovatum, Senecio triangularis,* and *Hydrophyllum occidentale.* This association is usually replaced later in the growing season by depauperate stands of *Rubus/Pteridium* or *Bromus/Rudbeckia* meadows.

Sambucus racemosa arborescens/Cardamine integrifolia sinuata/Campanula rotundifolia Talus Association

Steep talus piles of large rectangular blocks develop beneath high north-facing vertical faces of dense andesite. Vegetation in these piles is both sparse and of low diversity, but it is quite constant. Both shrubs and herbs are tolerant of burial of lower stems. Most of the herbs have primarily basal leaves, which reach the surface on long etiolated petioles. Other species are *Aquilegia formosa, Thalictrum occidentale, Acer circinatum,* and *Gentiana calycosa.* The gentian, which is faithful to these habitats, is ecologically, geographically, and morphologically distinct from other races of *G. calycosa* and merits taxonomic recognition, but no name has yet been proposed.

Selaginella wallacei/Saxifraga bronchialis vespertina/Penstemon rupicola Cliff-face Association

On dikes, cirque headwalls, or other steep erosional surfaces, slow weathering processes produce crevices and pockets that provide some protection from the excessive wind and insolation that characterize the adjacent habitats of the *Eriophyllum/Castilleja/Sedum* and *Lotus/Chrysothamnus/Allium* associations. Occasional small seeps provide moisture for these partially shaded areas until relatively late in the growing season, and they are exposed to moisture-bearing northwesterly winds but not dry easterly winds. It is thus a moister environment than those surrounding it, although drainage is usually extremely rapid. Occurring with the dominants are *Selaginella densa scopulorum, Polypodium hesperium, Arenaria rubella, Saxifraga cespitosa, Heuchera micrantha, Douglasia laevigata, Linanthastrum nuttallii, Polemonium pulcherrimum,* and *Castilleja rupicola.* Certain of these species, especially *S. bronchialis vespertina, D. laevigata, A. rubella, P. pulcherrimum,* and *C. rupicola,* grow only on the windward sides of the outcrops. If the outcrop does not face somewhat north of west, into the prevailing northwesterly winds, they are not likely to be found at all. This association is restricted to peaks having extensive outcrops of tuffaceous or friable rock, although the cliff-faces themselves are sometimes dense diabase intrusives.

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Short-Term Effects of Silicone Antitranspirant on Bird and Mammal Populations

Abstract

Aerial application of a 5 percent emulsion of polydimethysiloxane and a water carrier at a rate of 40 gal/acre had no short-term effect on rodent numbers or their reproduction in a cedar-hemlock watershed of northern Idaho. Song bird nesting was apparently unaffected also.

Chemicals are continually being synthesized and tested for possible employment in modifying environments for man's benefit. Testing procedures have been intensified in recent years to prevent use of chemicals with undesirable side effects such as those associated with the field use of chlorinated hydrocarbons. Silicones have a possible field application as antitranspirants to increase the volume of watershed runoff. Their low toxicity has been known for several decades (Rowe *et al.,* 1948), but the effects of field application on bird and mammal populations has remained unassessed. This study was undertaken to determine the possible effects of an aerial application of polydimethylsiloxane on bird and mammal populations of a coniferous forest in northern Idaho.

Study Area

The study area supports a mature stand of western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) on two small watersheds within the Priest River Experimental Forest, Bonner County, Idaho. Elevations range from 3,300 to 4,600 ft (1100-1530 m). Seral species present include western white pine (*Pinus monticola*), lodgepole pine (*P. contorta*) and western larch (*Larix occidentalis*). Douglas-fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*), climax species in other habitat types, are also represented. A shrubby understory is usually lacking. The upper parts of both watersheds support small numbers of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*), dominants of habitat types at higher elevations. Shrubs such as mountain maple (*Acer glabrum*) and huckleberry (*Vaccinium* spp.), occur in this ecotonal area. About 10 acres within the treated watershed were logged in 1940 and the second growth thinned in 1967. This area now supports a flourishing growth of conifers and a shrubby understory.

Methods

A 5 per cent emulsion of polydimethylsiloxane (Dow Corning) was applied to a 65-acre watershed on June 8, 1974, by helicopter at a rate of 40 gal/acre using a water carrier. An adjoining watershed of 51 acres served as a control.

Museum Special traps were set out in transect lines of 100 traps each on both the treated and control areas and maintained for two days weekly from one week prior

to treatment through seven weeks following treatment. Peanut butter was used as bait. Shrew populations were sampled by burying unbaited No. 10 cans to ground level. Nesting birds were censused weekly from June 19 through July 25 by mapping locations of singing males, a technique used in earlier studies (Kendeigh, 1944; Hensley and Cope, 1951). Red squirrels (*Tamiasciurus hudsonicus*) were censused in the same manner since none were captured in snap traps. Snakes and frogs were captured by hand. Specimens were necropsied to determine reproductive status. Litter size was determined by counts of visible embryos and placental scars. The decayed state of carcasses from can traps prevented an assessment of treatment effects on litter size of shrews.

Results and Discussion

Few rodents were trapped on either the treated or control areas, a result anticipated since cedar-hemlock habitat types support few rodents (Rickard, 1960; Hoffman, 1960). Treatment had no apparent effect on these populations. No significant ($P > .05$) difference in catch of deer mice (*Peromyscus maniculatus*), red-backed mice (*Clethrionomys gapperi*) or red-tailed chipmunks (*Eutamias ruficaudus*) occurred between sites (Table 1). Treatment had no effect on the litter size of deer mice, the only species caught in sufficient numbers to permit comparison. Breeding commenced several weeks before treatment and continued for at least a month afterward. Embryo counts and placental scars averaged 5 ($n = 7$) in mice from the control area and 5.4 ($n = 5$) in those from the treated area. Deer mice and red-backed mice produced two litters on both sites.

Table 1. Catch of rodents from snap traps and shrews from can traps.

	Control		Treated	
	N	Catch per 100 trap days	N	Catch per 100 trap days
Deer mouse	15	1.25	12	1.00
Red-backed mouse	4	0.33	3	0.25
Red-tailed chipmunk	6	0.50	8	0.67
Common shrew	18	1.10	10	0.57
Dusky shrew	16	0.98	13	0.75
Unidentified shrews	2	0.12	4	0.23

Red squirrels were sighted in about equal numbers on both treated and control areas. Few pocket gophers (*Thomomys talpoides*) were present and no attempt was made to estimate their numbers. There was some use of the study area by white-tailed deer (*Odocoileus virginianus*) and black bear (*Ursus americanus*) during the spring and early summer. Their movement to higher elevations during the summer was expected and not related to treatment.

Both the common shrew (*Sorex cinereus*) and the dusky shrew (*S. obscurus*) were taken in can traps on both sites (Table 1). A few additional shrews, including the water shrew (*S. palustris*), were taken in snap traps. There was no significant difference in the shrew catch from can traps between treated and control areas ($X^2 = 1.48$; 1 df; $P > .05$). The frequency distribution of shrew captures deviated significantly from the Poisson series ($X^2 = 15.9$; 2 df; $P < .05$) primarily because of greater than

expected numbers of can traps with no captures and multiple captures. Shrews probably are not randomly distributed throughout the trapping area, a plausible explanation for the large numbers of traps lacking a catch. The increased number of multiple captures may result from vocalizations of captured animals which attract other shrews to the trap.

Treatment had no measurable effect on breeding bird populations. Counts of singing males of five species differed little between sites (Table 2). Some males were probably counted more than once during multiple visits. The golden-crowned kinglet (*Regulus satrapa*) was the most numerous breeding bird on the study area. Territories of winter wrens (*Troglodytes troglodytes*) were easily identified because of their persistent singing from vantage points along roadsides. Swainson's thrushes (*Hylocichla ustulata* and evening grosbeaks *(Hesperiphona vespertina)* were best counted during the evening hours when singing was most frequent.

Table 2. Counts of singing males during five visits.

	Total Counts		Counts/Acre	
Species	Control	Treated	Control	Treated
Golden-crowned kinglet	20	19	0.39	0.29
Winter wren	9	13	0.17	0.20
Evening grosbeak	11	5	0.21	0.08
Swainson's thrush	4	10	0.08	0.15
White-breasted nuthatch	5	5	0.10	0.08

Other species occurring on the study area and likely nesting there include: Varied thrushes *(Ixoreus naevius),* western tanagers *(Piranga ludoviciana),* pine siskins *(Spinus pinus)*, mountain chickadees (*Parus gambeli*), chipping sparrows (*Spizella passerina*), Wilson's warbler (*Wilsonia pusilla*) and Audubon's warbler (*Dendroica auduboni*). Chipping sparrow and warbler nesting was restricted to shrubby sites on the upper slope and on the logged area.

There was some use of both sites by hummingbirds (species unknown), pileated woodpeckers (*Dryocopus pielatus*), Williamson's sapsuckers (Sphyrapicus thyroideus), northern three-toed woodpeckers (*Picoides tridactylus*), blue grouse (*Dendagapus obscurus*), goshawks (*Accipiter gentilis*), common night hawks (*Chordeiles minor*), ravens (*Corvus corax*) and Oregon juncos (*Junco oreganus*); but nesting by these species on the study area was not confirmed. Western garter snakes (*Thamnophis elegans*) and rubber boas (*Charina bottae*) occurred in small numbers on the logged section of the treated area. Pacific tree frogs (*Hyla regilla*) were found on both the treated and control sites.

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Schizoporella unicornis (Ectoprocta) in Coastal Waters of Northwestern United States and Canada

Abstract

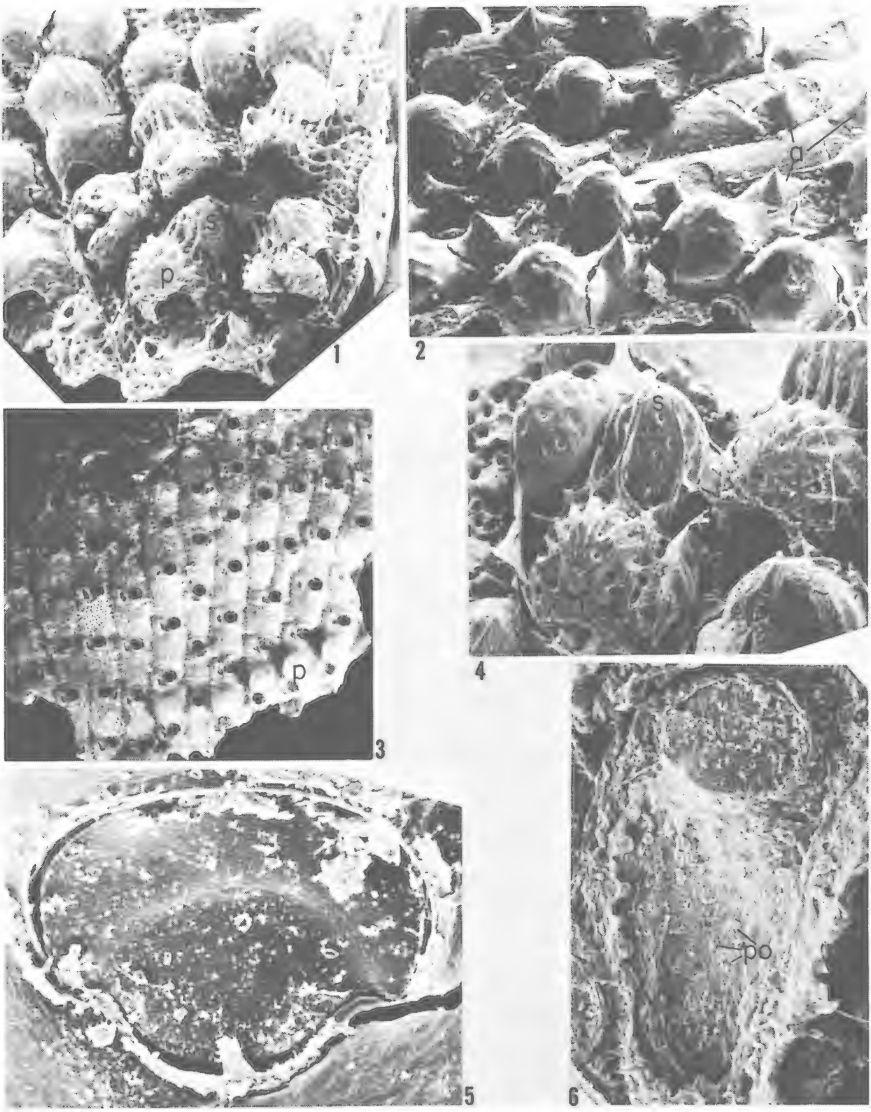
Schizoporella unicornis, an encrusting lower intertidal to shallow subtidal cheilostome, probably was introduced into Puget Sound between 1907 and 1927. This perennial species shows continued growth and reproductive activity throughout the year and has extensive morphological variability in zooecial features which reflects the diverse environments in which it occurs. Colonies that are permanently submerged in shallow surface coastal waters commonly have zooecia with multiple ooecia; however, multiple ooecia do not increase reproductive activity. The hypothesis that these multiple ooecia are the result of hyperplasia is unsupportable from our data. It is suggested that wide genetic variability for multiple ooecia in the different populations examined is favored because of the diversity of environments in which *S. unicornis* lives.

Introduction and Occurrence

Schizoporella unicornis (Wood *ex* Johnston), an encrusting cheilostome ectoproct (Figs. 1-6) that commonly forms a bright orange-colored colony, probably was introduced after 1900 from Japan into the marine fauna of the Pacific Northwest of the United States and British Columbia, Canada. Survey reports of bryozoans from the Pacific Northwest by Robertson (1900, 1908), O'Donoghue and O'Donoghue (1923, 1925a, 1925b, 1926) and Knox (1938) did not include this species. *S. unicornis* has been reported only recently from the Strait of Georgia, B.C., Canada, and San Juan Island, Washington (Powell, 1970), Willapa Bay, Washington (Powell, Sayce, and Tufts, 1970), and several other localities in Washington and in B.C., Canada (McCain and Ross, 1974).

Schizoporella unicornis, as observed in the coastal waters in the Pacific Northwest (Fig. 7), is principally a low intertidal species encrusting rocky substrates between 0.45 to 0.90 m below mean lower low water. It has not been found in dredge samples from Puget Sound and adjacent regions, whereas it has been collected subtidally from 20-30 m depth in Japan (Powell, 1970) and subtidally from Sydney Harbour, Australia. The species appears to be adapted to a wide range of environments.

Schizoporella unicornis is thought to have been introduced to Washington coastal waters with *Crassostrea gigas* seed from northeast Japan (Powell, 1970). *Crassostrea gigas* seed was imported to several states in the United States (California, Oregon, Washington, and Hawaii), British Columbia and to other parts of the world (Australia) to augment oyster culture. Imports of *C. gigas* seed began as early as 1907 (Steele, 1964) and many additional shipments arrived in the succeeding years, particularly during



Figures 1-6. Figure 1. S.E.M. surface view of *Schizoporella unicornis* with multiple ooecia per zooecium. Ooecia are perforate and radially sculptured where chitinous layer is lacking. Ooecia on left side of figure are covered with chitinous membrane. Ooecia on one zooecium are labelled: p—primary ooecium; s—secondary ooecium. Colony from subtidal waters, Port Hudson Marina, Port Townsend, WA. X 35. Figure 2. S.E.M. surface view of colony of *S. unicornis* with single ooecium per zooecium. Linearly ordered zooecia show one distinct avicularium (a) on each zooecium. Colony is covered by chitinous layer. Colony from intertidal waters, Post Point, Bellingham, WA. X 35. Figure 3. General view of colony of *S. unicornis*. Zooecia with primary ooecia in lower region of print are part of more proximal and older growth area. Colony from subtidal waters, Blaine Marina, Blaine, WA. X 10. Figure 4. S.E.M. surface

the 1920's and later. Although *S. unicornis* has only recently been identified in collections from Washington, California, and British Columbia, examination of earlier collections indicates that this species has been present for some time. Powell (1970) thought *S. unicornis* was introduced in the early 1930's, but specimens in the Kincaid Collection of the Shell Fisheries Laboratory, Nahcotta, Washington, provide evidence that the species was present in Samish Bay, Washington, as early as 1927, and the species was abundant in the southern reaches of Puget Sound by 1943. Hower (1938) had abundant specimens from Oakland Bay, Washington, in 1935 of a species (which he described but to which he did not assign a name) that probably was *S. unicornis*. Considering the history of importation of *C. gigas* seed, *S. unicornis* could have been introduced several times and in different places.

A similar history relating to *Crassostrea gigas* seed importation is found in Australia where *C. gigas* was introduced to Oyster Bay, near Albany, Western Australia, where it failed to survive, and to southern Tasmania where it thrived (Thomson, 1952). Since failing to find *S. unicornis*[1] in collections in Australia in 1973, we asked the assistance of marine scientists in Australia to be watchful for it. *Schizoporella unicornis* was not observed until early in 1975 when it was collected subtidally in Sydney Harbour, N.S.W., Australia.

Collecting Stations

Figure 7 locates 21 collecting stations. In addition, dried material from the Kincaid Collection of the Shell Fisheries Laboratory in Nahcotta, Washington, came from Samish Bay, Oyster Bay, and Shelton, Washington. Collections of *Schizoporella unicornis* were made between December, 1968, and June, 1975. Observations on growth and reproductive activity have been made monthly at the Blaine marina and intermittently at other stations, depending on accessibility and tidal conditions. Associated ectoproct species are recorded in McCain and Ross (1974).

The majority of the stations were docks or marinas located in estuarine areas where the species occurs on the submerged tread face and shaded outer sidewall and inner sidewall of hanging tires and on the lower surfaces of styrofoam floats. Where *S. unicornis* encrusts loose rock, the colonies generally occur on the lower side of large cobbles and on the protected lower surfaces of boulders, rather than on smaller (less than 20 cm diameter) rocks. Massive colonies cover much of the undercut section of a friable sandstone forming the shoreline at Post Point (station 13). At Nahcotta (station 19), the species encrusts oyster shells. It occasionally encrusts other substrates, *e.g.,* encircling the lower portion of the branched thallus of the green alga *Codium fragile* (Suringar) or it overgrows *Mytilus edulis* Linné, *Balanus crenatus* Brugière and a branching noncalcareous, yellow-tan sponge where tire communities of marine organisms are established. The ectoproct colonies overgrow barnacles and sponges but the larvae do not settle

[1] Allen (1953) recorded *S. unicornis* from more northerly Australian waters but his material in the Australian Museum that we have examined is referable to *Stylopoma* and not to *Schizoporella.*

view of multiple ooecia in *S. unicornis.* Colony from subtidal waters, Port Hudson Marina, Port Townsend, WA. X 70. Figure 5. S.E.M. surface view of operculum of zooecial opening of *S. unicornis.* Colony from intertidal waters, Post Point, Bellingham, WA. X 350. Figure 6. S.E.M. surface view of decalcified specimen in glycerol showing porous (po) frontal wall of zooecium of *S. unicornis.* Colony from intertidal waters, Post Point, Bellingham, WA. X 350.

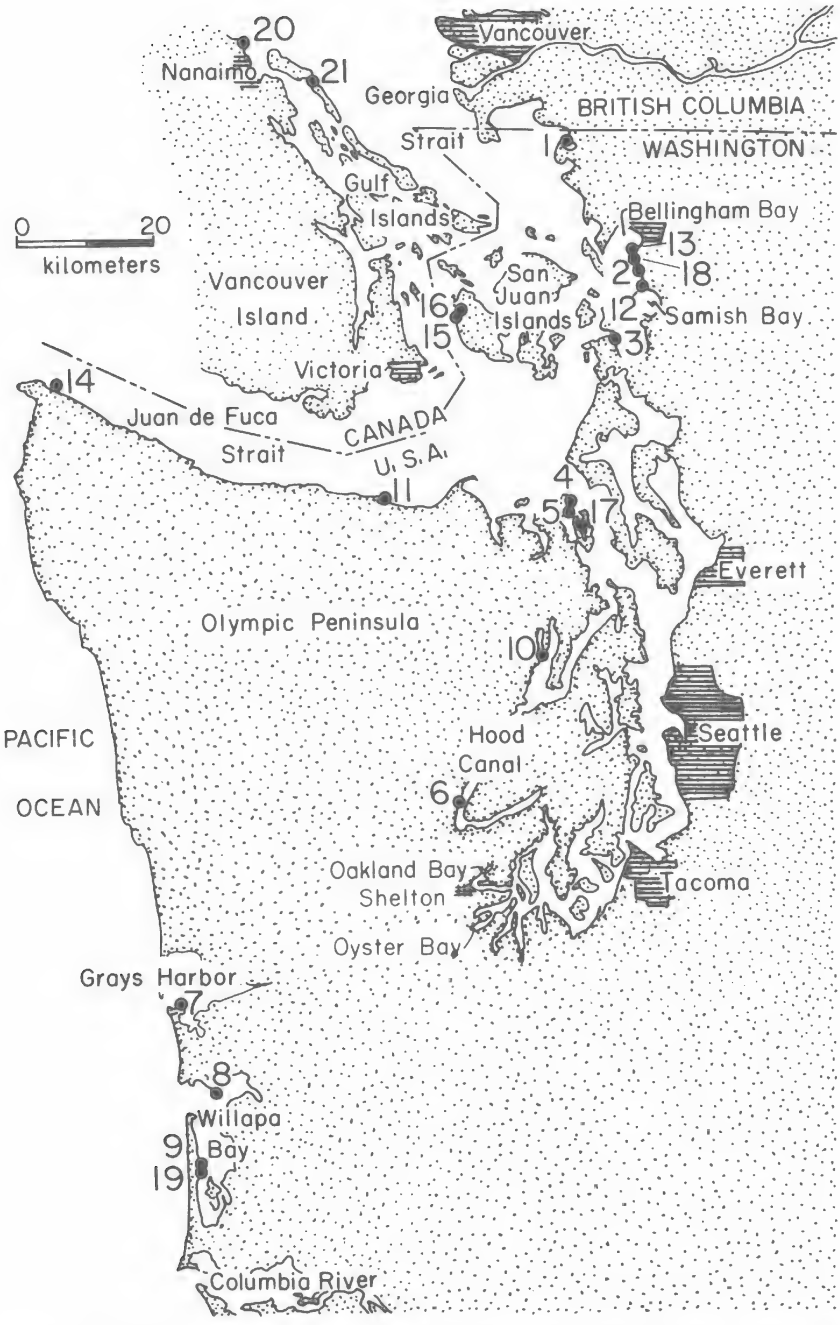


Figure 7. Location of collecting stations in Washington and British Columbia coastal waters. State of Washington: Littoral marinas (subtidal): 1, Blaine; 2, Pleasant Bay; 3, Anacortes Yacht Club; 4, Port Hudson; 5, Port Townsend; 6, Hoodsport; 7, West-

on them. Sometimes *S. unicornis* was overgrown by *B. crenatus* and the yellow-tan sponge.

Description of Schizoporella unicornis

Our material is identified as *S. unicornis* based on our comparison with the lectotype and syntypes in the British Museum and on discussions in Ryland (1968) and Powell (1970). *Schizoporella unicornis* was originally described from southern English waters by Wood (1844; see also Lagaiij, 1952). In North America, *S. unicornis* often has been recorded from the Atlantic Coast (Osburn, 1944; Rogick and Croasdale, 1949; and Maturo, 1959), but most of these occurrences are referable to the superficially similar species *S. errata* (Waters) (see Hastings, 1968; Powell, 1970). *S. unicornis* was reported to have world-wide distribution (Waters, 1909; Hastings, 1927; Ryland, 1965; and Powell, 1970), but each reported occurrence requires reassessment because of the taxonomic confusion between *S. unicornis* and *S. errata.*

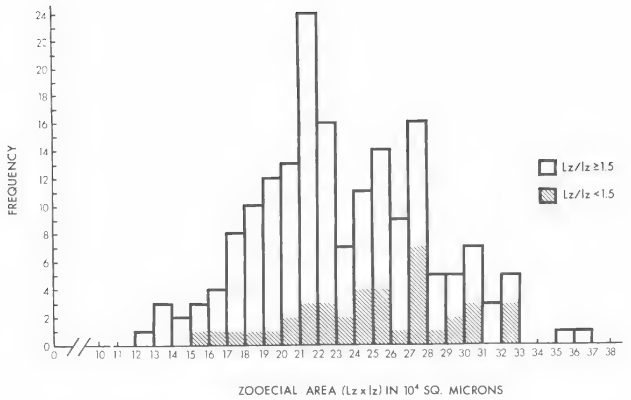
Typically mature, ooeciate colonies of this ascophoran species, *Schizoporella unicornis,* range from 1 to 4 cm in diameter (Fig. 3). The older central part of the colony may be white where zooids have ceased to regenerate. Crowding may restrict colony expansion along the boundaries between two different colonies but vigorous colonies seldom overgrow each other. Colonies may become foliate (stations 3 and 5) and appear bilaminar. No colonies showed frontal budding to produce true multilaminar expansions as described in *Schizoporella unicornis floridana* (Banta, 1972).

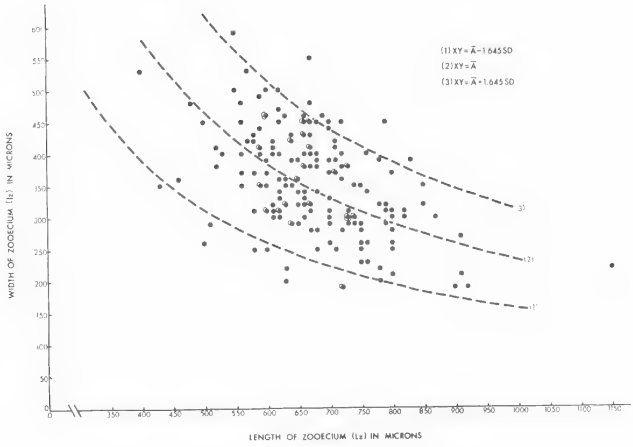
Only mature colonies were collected. In many colonies the earliest formed zooecia (generally in the central portion of the colony) are hexagonal whereas zooecia of the more recently formed middle and outer areas are rectangular (Fig. 3). The zooecia are arranged alternately in rows radiating from a central area. Most zooecia have greater length than width, but wider, squarer zooecia are distributed throughout a colony. Two daughter zooecia frequently arise from square zooecia. A histogram (Fig. 8) shows frequency of zooecial areas of square and rectangular zooecia. A scatter diagram (Fig. 9) plots zooecial length and width for a randomly sampled population. Zooecial outline in the species depends on the maturity of the colony and the spacing of individual zooecia (Figs. 8, 9). Ryland (1965) noted a similar change in shape in *S. unicornis* from Europe, but Powell (1970) described the zooecia of *S. unicornis* from British Columbia as hexagonal and the zooecia of *S. errata* as rectangular.

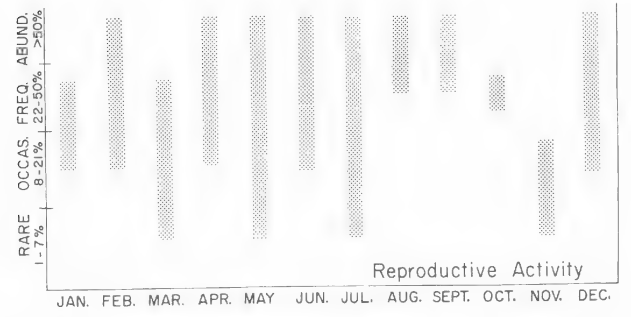
The zooecial opening is usually located distally in the midline of the frontal wall. It is wider than it is long, with a transversely arcuate distally outline with a shallow round proximal sinus and small cardelles (Fig. 5). A low peristome may expand to a thickened imperforate area just proximal to the sinus (Fig. 3). In some colonies this thickened area forms a small pointed umbo. The calcified frontal wall is inflated and perforate. These perforations are of two types (Banta, 1971); pseudopores which are closed by a skeletal membrane, and areolar pores which occur along the lateral boundaries of the zooecia (Fig. 6).

Typically one sessile adventitious avicularium lies adjacent to the lower border of

port; 8, Tokeland; 9, Nahcotta Bay boat basin; 10, Point Whitney; 11, Port Angeles. Intertidal: 12, Larrabee; 13, Post Point; 14, Waadah; 15, southwest of Mitchell Bay; 16, entrance to Mitchell Bay; 17, Nordland. Subtidal: 18, Edgemoor; 19, Nahcotta Bay (shucked shells). British Columbia: Intertidal: 20, Stephenson Points, north of Nanaimo; 21, False Narrows, Gabriola Island.







Figures 8-10. Figure 8. Histogram of frequency of zooecial areas of square ($Lz/lz < 1.5$) and rectangular ($Lz/lz \geq 1.5$) zooecia. The distribution of areas is skewed ($\bar{A}$=233,000 microns squared) and appears bimodal because of square zooids with large zoo-

the zooecial opening and projects outward (Fig. 3). Where paired, one of the avicularia may be displaced proximo-medially, particularly in ooeciate zooecia. Rarely, avicularia may appear in other locations, *e.g.,* between zooecia, or low on the frontal wall, just distal to an ooecium. Occasionally large colony expanses lack both ooecia and avicularia.

The hyperstomial ooecium (Figs. 2, 3) is globose, with radiating ridges which may be pronounced. Fine perforations between the ridges are visible in dried specimens but generally cannot be seen in wet specimens (Figs. 1, 2, 4). Perforations in the ooecia of *S. unicornis,* not noted by Ryland (1965), were described by Powell (1970).

In comparison to *Schizoporella errata, S. unicornis*: 1) lacks the frontal avicularium and extended proximal cusps on the ooecia as found in *S. errata;* 2) has an inflated frontal wall whereas that of *S. errata* is flat; and 3) has a zooecial opening which is typically median and upright and transversely arcuate with a shallow proximal sinus, whereas in *S. errata* the zooecial opening is well rounded and rotated outward and the sinus is deep.

Ecological Requirements

Schizoporella unicornis, Bugula pacifica Robertson and *"Conopeum"* sp. appear to have an overlapping pattern of distribution. The settlement of these species on substrates in estuarine areas and marinas often subjects them to a wide range of salinities and, while they can apparently tolerate a wide short-term variation in salinity, the long-term average salinity more closely relates to their distribution. The salinity range for *S. unicornis* is about 18 ‰ to 30 ‰ . *Schizoporella unicornis* and *"Conopeum"* sp. have not been found where the long-term salinity is near oceanic levels, *i.e.,* 30 to 33 ‰ . Most stations in our study show a maximum salinity of 28 to 28.5 ‰. In the Puget Sound Basin and immediately adjacent regions, the surface water temperature ranges from 7.5° to 16°C. On the Pacific Coast at Willapa Bay, a shallow bay with a restricted entrance, the surface water temperature ranges from 7° to 19°C (from hydrographic data, Washington Department of Fisheries).

Industrial waste products from paper pulp mills and other plants, such as spent sulphite liquor and waste water, modify the environment so that *Schizoporella unicornis* does not occur in the immediate regions of outfall of such industrial waste products. *Schizoporella unicornis* occurs at stations on and near Bellingham Bay where the spent sulphite liquor in the surface water layer averages 40 to 50 p.p.m. (data from U.S. Dept. Interior Report, 1967). It does not occur where spent sulphite liquor is 100 to 200 p.p.m.

Another factor affecting the distribution of *Schizoporella unicornis* is the presence of a suitable substrate. As observed in the laboratory, larvae of *S. unicornis* become negatively phototactic within a short period after release, and, therefore, in the low intertidal and subtidal regions, they settle on the lower surfaces of large immovable objects. *S. unicornis* generally does not encrust rocks less than 20 cm diameter and it

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ecial areas. Figure 9. Scatter diagram plotting zooecial length and zooecial width of 180 zooecia from mature colonies at 9 collecting stations. Curves of the calculated mean and the upper and lower 5 percent confidence limits for a normal population are indicated. Figure 10. Monthly reproductive activity determined as percentage of ooecia with embryos to those ooecia without embryos for collecting stations 1 to 17.

is not found in much of the cobbled intertidal areas. Float and bumper tires provide a uniquely appropriate substrate for *S. unicornis*—a large flat shaded surface that is free from abrasion, including a lower surface free from settling detritus and exposed to water currents with a supply of food.

Growth and Reproductive Activity

Schizoporella unicornis is a long-lived perennial species which broods its young in a specialized chamber, the ooecium. Some colonies at station 3 (Anacortes) and some maintained in an aquarium survived for at least three years. Growth and reproductive activity are continuous throughout the year. The growing edge of the colonies shows development throughout the year and maximum activity in the spring and summer. In our studies, settlement of larvae at an open bay site north of Puget Sound (station 1, Blaine) occurs throughout the greater part of the year, falling off in late February and March. Older colonies possess a larger number of embryo-bearing individuals. The maturing embryos in ooecia are approximately 250 microns in diameters and range from deep red-orange to orange. Increasing maturity of the embryo is paralleled by a decrease in color intensity from red to orange. Generally at any time only one embryo is brooded in an ooecium, although the rare situation of two embryos in an ooecium (one orange-colored and the other deep red) has been observed. Two dark pigment spots are visible in mature embryos. They fluoresce red when light strikes them. In the laboratory release of embryos from ooecia was triggered by bright light from a microscope lamp.

Reproductive activity was determined by noting the relative abundance of embryos in ooecia at several of the collecting stations each month. Observations were based on up to 50 colonies. Areas between 0.25 cm^2 and 1 cm^2 of mature colonies were scanned for number of ooecia with embryos and for the number of zooecia with ooecia. The ratio of ooecia with embryos to zooecia with ooecia in a particular area of a colony gave a level of reproductive activity. This procedure is similar to that followed by Ryland (1967) and Gordon (1970). Reproductive activity showed fluctuations (Fig. 10) but it continued throughout the year in colonies located in the inner estuarine areas of Washington. At any one station colonies commonly showed marked variation in reproductive activity. Colonies produced embryos at the highest level of reproductive activity in most months of the year, although reproduction declined in some colonies in October and November. Powell (1970) also noted that embryos were present over a 12-month period in colonies from the Strait of Georgia.

Hower's (1938) observations of a common but unnamed species of *Schizoporella* in Oakland Bay, an inner bay at the southwestern end of Puget Sound, Washington, showed that this species had a period of maximum settlement from mid-June to mid-September. Settlement began in early May and generally ceased completely in early October, although for one year settlement continud into November. The species occurred in the intertidal region at 3.5 to 5.5 m. Hower suggested that higher temperatures and high chlorinity favored the seasonal settlement and the growth of this species of *Schizoporella.* A comparison of Hower's data from Oakland Bay and of our studies at various locations suggests that settlement is more continuous where tidal flushing action is strong in Puget Sound Basin. Oakland Bay is remote from the opening to the Puget Sound Basin and the flushing action of the deeper sea-water layer is more sluggish, as demonstrated by experiments in the Puget Sound tidal basin model, University of Washington.

Settlement data for the warmer water species, *Schizoporella errata,* show that larvae settle from April to November in Beaufort, North Carolina (Maturo, 1959; McDougall, 1943) and from March to November in Daytona Beach, Florida (Richards and Clapp, 1944). *S. errata* had two periods of abundant settling which correlated with the two seasons of the year when the mean water temperature was approximately 22° to 25°C (McDougall, 1943). Year-round settlement was recorded for a species identified as *S. unicornis* in Hawaii (Edmondson and Ingram, 1939; Edmondson, 1944). So far, material from Hawaii that we have examined has been referable to *S. errata* and the species of *Schizoporella* from Hawaii illustrated by Soule and Soule (1968, pl. 2, fig. 5) is not *S. unicornis.*

The continuous growth and reproductive activity of *Schizoporella unicornis* suggests that the environmental parameters which sustain these colonies operate at near optimal levels throughout most of the year in the coastal waters of Washington and British Columbia. Colony growth and reproductive activity are not affected appreciably by seasonal changes. The upwelling of cool, nutrient-rich seawater along the Washington coast which results in the continual mixing of water and the addition of nutrients to the surface water layers may be a significant factor in promoting the constant growth of *S. unicornis* in this region. This species thrives where colonies are continually submerged in shallow seawater.

Multiple Ooecia

In many colonies of *Schizoporella unicornis,* some individual zooids produced more than one ooecium at different growth stages of a colony (Figs. 1, 4). This exceptional multiple ooeciate phenomenon was described first by Hincks (1880) in *S. dunkeri* Reuss (as identified by Ryland, 1968) in material from south Devon waters, British Isles. Multiple ooecia were again noted by Powell (1970) in material from British Columbia and northeast Japan. Colonies with multiple ooecia occur at 13 of our 21 stations (Fig. 7). Multiple ooecia are more abundant in colonies located at marina stations where there is less wave action and the colonies are submerged continuously. The number of multiple ooecia varies considerably between colonies and from station to station. Primary ooecia and secondary multiple ooecia show no structural differences other than size. A primary ooecium is the single ooecium that develops distally to the zooecial opening in most cheilostomes. A secondary ooecium is an additional ooecium not located in the primary position and is smaller than the primary ooecium. Secondary ooecia (Figs. 1, 4) occur in a variety of positions with respect to the zooecial opening: 1) as a single ooecium either proximally (opening above the sinus) or distally (atop of the primary ooecium); 2) as single or paired ooecia flanking the primary ooecium; 3) on the proximal border of the zooecial opening with a distal primary ooecium; or 4) in any combination of the above. Some colonies lack primary ooecia and possess only one or more small secondary ooecia. At stations 3, 4, 5, and 19, one or more colonies had only single proximal secondary ooecia. The number of multiple ooecia per zooecium increases with age of the colony; the greatest number of ooecia and greatest diversity of arrangement are in the central (older) region of a colony. At stations 2, 6, and 13, the secondary ooecia were rare and scattered throughout the colonies.

We observed embryos in the secondary multiple ooecia, which establishes that they are used as brood chambers. Primary and secondary ooecia on the same zooecium have not been observed to brood embryos at the same time. Therefore, the multiplication of

additional ooecia does not appear related to increased reproductive activity and an explanation for its significance has not yet been determined. Other cheilostome species at the stations we examined produced neither multiple ooecia nor evidenced other visible morphologic abnormalities.

Previous Hypothesis of Hyperplasia

Because the secondary multiple ooecia are consistently present in natural populations of *S. unicornis,* the phenomenon is not interpretable as hyperplasia as suggested by Powell, Sayce, and Tufts (1970). The term hyperplasia refers to an increase in cell number (Bresnick, 1970) within an organ or structure. Hyperplasia can be induced by many different agents; *e.g.,* various carcinogenic compounds, parasitic and viral infections, and even deficiency of a particular hormone. Farber (1970) noted that hyperplasia often develops long after the carcinogen is removed from the environment, and that, while the carcinogen-induced hyperplasia is not cancerous in itself, it appears to be a precursor to cancer. Hyperplasia also exhibits a certain disorganization of structure; this disorganization increases as the tumor becomes cancerous. The "hyperplasia" as described by Powell *et al.* (1970) is not disorganized—the secondary ooecia do not differ in structure from the primary ooecia—and the secondary ooecia have not been observed to become cancerous or otherwise pathogenic; indeed, colonies collected at marina stations with large numbers of multiple ooecia are healthy and extremely fertile and sectioned material has revealed no sign of disorganized growth or tumor formation.

Powell *et al.* (1970) reported that multiooeciate zooecia could be induced in "normal" colonies in seven to nine days by placing them in close proximity to creosote and asphalt treated oyster trays in Nahcotta Bay, or by suspending shells encrusted by *Schizoporella unicornis* in the Nahcotta boat basin. They described these multiple ooecia as a hyperplasia induced by coal-tar derivatives from the asphalt, creosote, or oil. Sayce (personal communication, 1971) noted that it had not been possible to induce growth of multiple ooecia in the laboratory using hydrocarbons. In our study, colonies from station 2 which had no secondary ooecia when brought into the laboratory produced secondary ooecia throughout the older parts of the colony within six weeks of being maintained in an aquarium free of contaminants. At station 2 multiple ooecia occur in the colonies but are not as prolific as at some other stations.

Summary

From our observations, colonies of *S. unicornis* which are permanently submerged display multiple ooecia more consistently than do colonies from intertidal stations. Thus higher frequencies of multiple ooecia occur in a specific environmental setting. The encrusting ectoproct species has a mixture of phenotypes that display great morphological variability which could reflect broad environmental heterogeneity. Depending on the location where colonies are established, they will encounter different factors (*e.g.,* variations in temperature, food, day length, light, or water current velocity). According to Levins' (1968) theory of strategies of adaptation, the proportions of different environmental factors are constant throughout the species range, but the environment is uncertain for each colony. Thus the optimum strategy for *S. unicornis* may dictate that specialized morphs *(i.e.,* phenotypically variable zooecia) occur in frequencies dependent on the frequencies of the environmental factors.

At all stations in our study *Schizoporella unicornis* was the only cheilostome which produced multiple ooecia. This observation together with the recorded occurrence of multiple ooecia in *S. unicornis* from northeast Japan suggests that production of multiple ooecia has a genetic rather than a strictly environmental basis. The abundance of *S. unicornis* in estuarine areas, particularly in marinas, suggests that the multiple ooeciate phenomenon is not being actively selected against and may be part of a general adaptive complex that is being selected for. Variable numbers of multiple ooecia in colonies at various stations and often between colonies at the same station suggest that the development of multiple ooecia reflects responses to environmental stimuli.

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Small Mammal Populations near the Trojan Nuclear Power Station, Oregon[1]

Abstract

A small mammal live trap-mark-recapture survey was made in Douglas-fir forest and grassy meadow habitats at the Trojan nuclear power station, Oregon, during 1972 and 1973. Seven species were caught; the deer mouse, *Peromyscus maniculatus,* was most abundant. More small mammals were captured in the forest than in the meadow habitat. Jumping mice, *Zapus trinotatus,* and Townsend voles, *Microtus townsendi,* were caught only in the meadow habitat. Townsend chipmunks, *Eutamias townsendii,* were caught only in the forest habitat.

On the average, male deer mice weighed more than females. Females were reproductively active at all seasons. Bot fly infestations were more pronounced in the forest animals than in meadow animals. One male deer mouse lived on the study plot for 21 months.

Introduction

Small mammals are widely distributed and often abundant in terrestrial ecosystems in North America, and they provide an important food base for mammalian, reptilian, and avian predators (Hall and Kelson, 1959). At times, small mammals are regarded as pests. In forested regions, deer mice, *Peromyscus maniculatus,* eat the seeds of Douglas-fir trees (Gashwiler, 1971). Individually, deer mice under confined conditions can consume more than 200 Douglas-fir seeds in a single night, a problem that is particularly acute when artificial seeding is used as a reforestation practice (National Academy of Science, 1970).

Usually small mammals are more amenable for population studies than are medium or large mammals, partly because small mammals are abundant and have small territory requirements; some may spend their entire lives confined to a few acres of suitable habitat. Some small mammals are readily captured in live traps and individual animals can be recaptured again and again offering opportunity to examine individuals in hand for weighing and observations of general health.

This paper presents the results of a 21-month mark-recapture study of small mammal populations near the Trojan nuclear power station and contributes to the state of knowledge of forest and meadow habitats of western Oregon. The study was initiated to establish baseline data to monitor the effects, if any exist, of nuclear power plant operation on small mammals.

The Site

The Trojan nuclear power station is located adjacent to the west bank of the Columbia River near the village of Prescott, Columbia County, Oregon. The site consists mostly of

[1] This work was performed for the Portland General Electric Company, Portland, Oregon.

second growth forest, meadow, and marshlands. Uplands with well-drained soil support coniferouse forest stands dominated by Douglas-fir, *Pseudotsuga menziesii.* Wet soils support stands of Oregon ash, *Fraxinus latifolia,* and black cottonwood, *Populus trichocarpa.* Marshlands contain mostly reed canary grass, *Phalaris arundinacea,* and shrub willows, *Salix* spp. Meadows of perennial grasses are mowed annually.

The site has undergone more than a century of land use. One railroad and a highway cross the site. The existing forests are second growth stands crisscrossed with abandoned logging roads. A few aged fruit trees mark the location of abandoned farmsteads. About 40 acres of land are presently devoted to buildings, parking lots, outdoor storage space, and surfaced roadways designed to service the nuclear power station. Landscaping consits of the development of a reflection pool and the planting of lawn grasses and ornamental trees. However, the major part of the 80 acre property is undeveloped and provides habitat for wildlife.

Methods

Twenty-five Sherman live traps were distributed at approximately 15-meter intervals along each of two different trails. One trail was in a Douglas-fir forest and the other along a meadow edge. Traps were opened in the afternoon and visited in the early morning for two consecutive trap nights. Sixteen sessions, mostly at monthly intervals, were conducted between April 1972 and December 1973.

Trapped animals were individually marked using toe amputations. Animals were weighed using a delicate spring balance, identified to species, examined for sex, approximate age, reproductive condition, and the occurrence of bot fly larvae or their scars. All animals were released near points of capture.

Traps were supplied with mixed seeds and grain to help sustain animals during their stay inside the traps. A wad of soft Dacron material was also supplied to act as thermal insulation to help maintain body heat. A small quantity of an oatmeal-peanut butter mixture was placed on the door for bait when the traps were set.

Trapping Results and Discussion

Seven species of small mammals were taken from the two trap lines (Table 1). The deer mouse was the most often trapped small mammal. Townsend chipmunks were also more frequently trapped than the remaining five species, although they did not occur in the meadow. Jumping mice and Townsend voles did not occur in the forest community. Only the deer mouse was captured often enough to yield information concerning sex ratios, longevity, seasonal changes in body weights, and trapability.

Deer mouse captures in the forest were highest in the early spring of 1972. Catches steadily declined with the lowest success in the spring of 1973. The catch increased in the fall of 1973. Too few captures were made in the meadow habitat to identify trends.

More male than female deer mice were captured, which probably reflects the greater mobility of males. The recaptures of 25 deer mice marked in April 1972 were followed through December 1973 and are illustrated in Table 2. One male deer mouse remained on the trap line after 21 months. The longest persistence time on the trap line for females was only eight months. On the average, male deer mice weighed more than females. Weights of females and males fluctuated according to reproductive condition as well as age.

Date	Deer Mouse *Peromyscus maniculatus*	Townsend Chipmunk *Eutamias townsendi*	Oregon Vole *Microtus oregoni*	Vagrant Shrew *Sorex vagrans*	Shrew Mole *Neurotrichus gibbsi*	Jumping Mouse *Zapus trinotatus*	Townsend Vole *Microtus townsendi*
				Forest Plot			
1972							
Apr	25	2	0	0	0	0	0
May	27	8	1	0	0	0	0
Jul	16	4	0	0	0	0	0
Aug	15	11	0	0	0	0	0
Sep	17	13	2	1	0	0	0
Nov	15	2	1	0	0	0	0
1973							
Jan	5	0	0	0	0	0	0
Mar	2	0	1	0	0	0	0
Apr	3	6	0	0	0	0	0
May	5	5	0	0	0	0	0
Jun	6	5	1	0	0	0	0
Jul	5	1	0	0	1	0	0
Aug	2	0	1	0	2	0	0
Sep	6	0	2	0	2	0	0
Oct	12	0	0	0	0	0	0
Dec	9	0	0	0	0	0	0
Total	170	57	9	1	5	0	0
				Meadow Plot			
1972							
Apr	----------	----------	----------	Not Trapped	----------	----------	----------
May	11	0	0	1	0	4	1
Jul	5	0	0	0	0	0	1
Aug	9	0	0	1	0	0	0
Sep	2	0	0	0	0	0	0
Nov	4	0	0	0	0	0	2
1973							
Jan	7	0	0	0	0	0	0
Mar	4	0	3	0	0	0	0
Apr	5	0	1	1	0	0	0
May	4	0	2	0	0	2	0
Jun	2	0	2	1	0	1	0
Jul	0	0	0	0	0	1	1
Aug	3	0	0	0	0	0	0
Sep	1	0	0	0	0	0	0
Oct	1	0	0	0	0	0	0
Dec	0	0	0	0	0	0	0
Total	58	0	8	4	0	8	5

TABLE 1. Monthly trap catch of small mammals on forest and meadow trap lines at the Trojan nuclear power station, Oregon, 1972-73.

Infestation by Bot Fly Larvae

During routine trapping, infestations of small mammals by the larvae of *Cuterebra* sp. were observed. The larvae were first noted in August 1972. Four of the 24 deer mice and three of the 11 chipmunks captured showed evidence of cuterebrid infestations. In September only one of 19 deer mice and one of 13 chipmunks were infested. Cuterebrid larvae were not found again until August 1973, when one of five deer mice captured contained larvae. Late summer to early fall is considered to be the bot fly season (Hunter *et al.*, 1972). Blair (1942) observed that in Michigan there was a correlation between a forested environment and the presence of *Cuterebra* sp.

There were too few recaptures to make any determination of detrimental effects of bot fly infestations on either individuals or the population. Conflicting results have been reported from studies on longevity of infested mice (Wecker, 1962; Hunter *et al.*, 1972).

Reproductive Activity of Deer Mice

The deer mice on the Trojan station exhibited no significant seasonal reproductive behavior. Female *P. maniculatus* which were noted as being reproductively active were

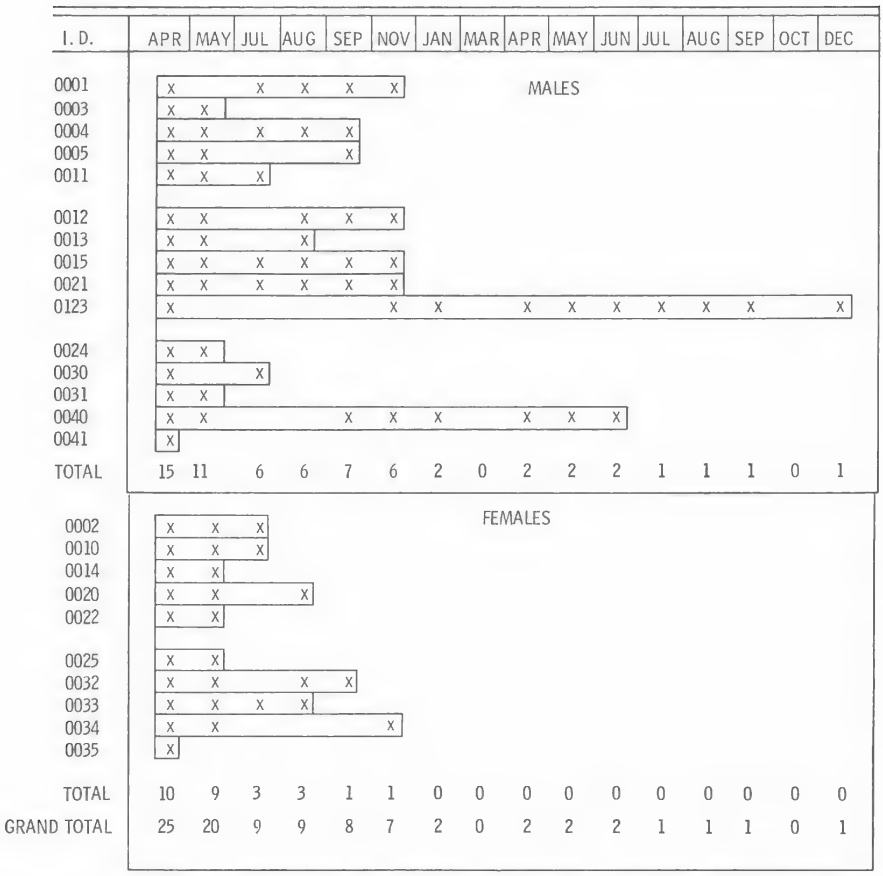

TABLE 2. Persistence of deer mice caught in the forest trap line over a 21-month period, April 1972 to December 1973.

captured during all seasons of the year. Kritzman (1970) reported that breeding of *P. maniculatus* in the desert steppe of south-central Washington appeared to cease during times of environmental extremes. The environmental stresses imposed upon small mammals living in a coastal forest ecosystem are probably less severe *i.e.,* in terms of heat, cold, and snow cover.

Indices used for classification as breeding or nonbreeding condition can be somewhat arbitrary. A study in southwestern British Columbia and western Washington describes a lack of reproductive activity in early winter by *P. maniculatus* (Sheppe, 1963). However, Sheppe did not consider some animals in early pregnancy or in estrus to be in breeding condition. In this study, all females showing signs of estrus, pregnancy, or post partum were considered reproductively active.

Relationship to Other Vertebrates

Avian predators were scarce at the Trojan site. The most important bird that can kill

and feed upon small mammals is the great blue heron, *Ardea herodias.* Herons are important in meadow and marsh-pond habitats but not in forests. Garter snakes, *Thamnophis sirtalis* and *T. ordinoides,* were abundant in meadow habitats and these could be important predators on small mammals, especially in warmer seasons that are favorable to increased metabolic activities of these cold-blooded vertebrates. Mammalian predators include the least weasel, *Mustela rixosa,* and red fox *Vulpes fulva.* The latter could well be an important predator on small mammals at the Trojan site since it ranges through many terrestrial habitats.

Relationships to Plant Growth and Reproduction

Deer mice can consume large quantities of Douglas-fir seeds, and these could cause serious losses to artificially disseminated seeds. However, most of the acres that can sustain Douglas-fir trees are already well stocked by natural reproduction.

Meadow mice have high reproductive potential and can reach population densities great enough to harvest substantial amounts of plant production. Economic losses can be attributed to decreased yields of grass or alfalfa. Although meadows at the Trojan site are cut for hay, maximum forage production is not a goal of management, and rodent control is not practiced.

Relationship to Power Station Operation

The data obtained in this investigation identify the species of small mammals living at the Trojan site and yield some indication of their relative abundance. The density of small mammals fluctuates with births, deaths, immigration, and emigration.

The most apparent terrestrial environmental impact of the operation of the nuclear power station will probably be the water vapor plume emanating from the cooling tower and the associated drift which consists of small droplets discharged into the surrounding air. These droplets will be deposited over adjacent landscapes throughout the 30-40 year operational life of the power station. Drift contains dissolved minerals associated with the coolant water as it is drawn from the Columbia River.

This study is expected to detect gross changes in small mammal populations attributable to the accumulation of minerals dissolved in coolant water or changes caused by logging and wildfire should these occur on the established study area. Laboratory studies utilizing conventional biological assay techniques using wild, small mammal stock would be useful in identifying more subtle long-term effects of cooling tower effluents on general health and reproductive capability of small mammals.

Acknowledgments

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Characteristics of the Natal Den of the Badger

Abstract

Natal dens of three badgers (*Taxidea taxus*) in northwestern Utah and southeastern Idaho were characterized by a single main tunnel which branched into two secondary tunnels that later rejoined. Two of the dens had two chambers and one had a single chamber. An average of eight tunnels less than 15 cm in length (pockets) and eight dead-end tunnels ($\bar{x} = 1.1$ m) were found in the walls of the main and secondary tunnels and chambers. Pockets were filled with scats and dead-end tunnels with loosely packed soil and scats.

Introduction

Activities of badgers center around the use of underground dens. Primarily nocturnal, they rest in dens during daylight hours and through a majority of the year rarely spend more than one day without emergence in a given den. Extended use (two to six days) of a single den becomes more frequent as activity is restricted during the winter months (Sargeant and Warner, 1972). However, the greatest long-term demand placed on a den is during a four to eight week period in the spring when the female gives birth to and raises young (Lindzey, in preparation). Because badgers characteristically dig their own dens, the construction of the natal den should reflect the functional needs of the female and young.

Methods

During 1969-1970 five natal dens were located in Curlew Valley of southeastern Idaho and northwestern Utah. Sagebrush (*Artemesia tridentata*), the dominant natural vegetation in the valley, was interspersed with cereal-grain plantings and crested-wheat grass (*Agropyron cristatum*) seedings.

External characteristics of natal dens used in differentiating them from day-use dens were: (1) a soil mound at the entrance generally over twice the size of those of day-use dens (principally freshly deposited soil); (2) more numerous tracks on the mound indicating frequent trips to and from the den (adult and later young); and (3) abundant badger hair mixed with soil comprising the mound. The presence of hair throughout the soil mound was the most reliable criterion for identifying natal dens.

Three of the dens were subsequently excavated. Sketches were made as the excavations progressed and locations identified where scats were found. Measurements were taken of the lengths and depths of the tunnels and pockets of two of the three dens.

Results and Discussion

Only one of the three dens had more than a single entrance. Apparently this second entrance, which showed little sign of use, had been an entrance to a day-use den

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Two of the dens contained young at the time of excavation. The third den was excavated after the departure of the female and two young.

Results and Discussion

Only one of the three dens had more than a single entrance. Apparently this second entrance, which shows little sign of use, had been an entrance to a day-use den contacted during construction of the natal den. Characteristics of construction common to the three dens were: (1) a main tunnel that branched into two secondary tunnels which later rejoined; (2) dead-end side tunnels projecting from the chambers and main and secondary tunnels; (3) pockets (15 cm or less in length) in the sides of the chambers and main and secondary tunnels; (4) shallow depressions in the tunnel floors; and (5) chamber(s) (Fig. 1). The deepest of the dens was 2.3 m at its maximum depth; the other was 1.3 m.

The secondary tunnels of two of the dens remained in generally the same horizontal plane following their formation whereas one secondary tunnel of the third den dropped to a level approximately 30 cm below the other before they rejoined. As suggested by Thomas (1974), branching of the main tunnels may allow animals to pass one another in the system. Each den had one or two chambers, 46-54 cm in diameter. One chamber in each den was located at the point where the two secondary tunnels rejoined. An average of eight dead-end tunnels ranging in length from 0.6 to 1.5 m ($x = 1.1$ m) and eight pockets (tunnels less than 15 cm) were found in the walls of the main and secondary tunnels and chambers. Pockets appeared similar in function to the "fecal chambers" described by Martin (1971) in the burrow system of mountain beavers

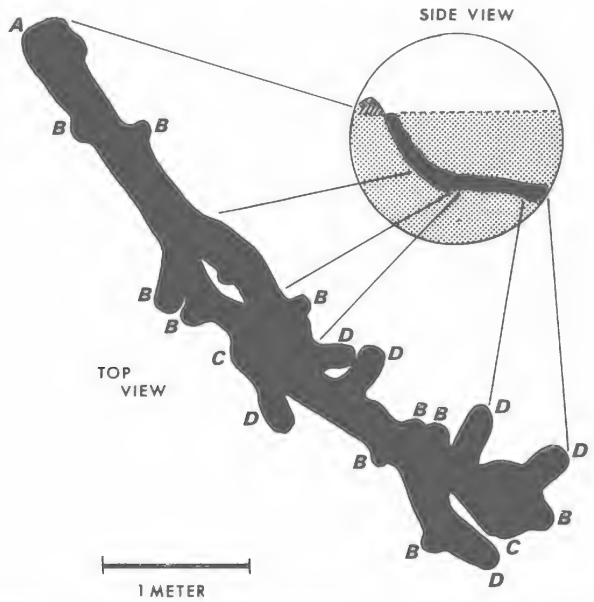

Figure 1. Composite diagram showing characteristics of natal den construction of the badger. Letters represent: A, entrance; B, pockets; C, chambers; D, dead-end tunnels.

(*Aplodontia rufa*). Each pocket contained one or more scats which had been covered with soil. Dead-end tunnels were filled with both scats and loosely packed soil. Some loose soil from digging in the den was apparently moved into the dead-end tunnels rather than out of the den. Scats were occasionally found in shallow (approximately 5 cm) depressions in the tunnel floors. No nest material was found in the dens.

Acknowledgment

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Running Speeds of Crippled Coyotes[1]

Abstract

Running speeds of one uninjured coyote (*Canis latrans*) and three coyotes crippled by loss of use of one front foot were recorded as the animals were chased through measured courses by a person on foot. The crippled coyotes generally attained slower speeds than did the uninjured coyote. Mean speeds for the crippled coyotes ranged from 19.1 kph to 27.4 kph.

Introduction

Young and Jackson (1951:99-105) reported several accounts of coyotes surviving loss of part of an appendage resulting from gunshot or damage from a steel trap. Such an injury may affect the speed a coyote is capable of attaining, thus influencing prey-capture and escape capabilities.

Cottam (1945), Sooter (1943), and Zimmerman (1945) reported running speeds of presumably uninjured coyotes being chased by car. Recorded speeds ranged from 46.7 kph to 69.2 kph. Speeds of coyotes lacking all or a part of one foot apparently have not been recorded.

On 21, 22, and 23 October 1974 I recorded running speeds of three wild-trapped coyotes that had lost the use of one foot due to damage from a steel trap. On 21 January 1975, I recorded speeds of an uninjured coyote for comparison.

Methods

The coyotes were confined in cages within a 6.5-ha cyclone fence enclosure located 17.8 km northwest of Corvallis, Oregon. During the tests, the coyotes were released from their cages singly and allowed to run along the perimeter fence of the enclosure. Each day the coyotes were timed with a stop-watch as they ran three measured courses (97.6 m, 112.7 m, and 152.4 m) along the perimeter fence. As a coyote approached the starting point of each course, I chased the animal on foot at a distance of 45 m to 70 m. Each coyote ran approximately 1220 m each day but was chased through the measured courses only. I recorded speeds for the uninjured coyote on one day only because of difficulty in handling the animal. Weather and ground conditions were similar on all test days.

Results

Speeds attained by the crippled coyotes generally were less than the speeds of the uninjured coyote, although one crippled animal equalled the performance of the uninjured coyote (Table 1). The speeds for three timed runs by the uninjured female on 21 January were significantly greater ($t = 3.61$,2 df,$P < 0.05$) than speeds for three timed

[1] Technical Paper No. 4066, Oregon Agricultural Experiment Station.

runs on 21 October by the crippled female of comparable size. The speeds recorded for the crippled coyotes appeared to be directly related to the weight of the animals.

TABLE 1. Physical descriptions, number of runs, maximum speeds, and mean speeds for three crippled coyotes and one uninjured coyote chased through measured courses.

Sex	Weight (kg)	Condition of front feet	Number of timed runs	Speed (kph)	
				Maximum	Mean
F	7.7	RF foot degenerated	9	25.4	20.9
M	10.4	LF foot amputated	9	31.9	27.4
F	5.4	RF foot amputated	9	22.5	19.1
F	7.3	Undamaged	3	31.9	27.5

Although the crippled coyotes occasionally contacted the ground with their damaged appendage, they typically adjusted their stride to prevent contact with the ground. The adjusted stride resulted in a noticeable bouncing movement when the crippled coyotes ran.

Discussion

The coyotes were held in captivity for at least three weeks prior to the tests and were somewhat accustomed to me. This familiarity and the slow speed at which I chased the coyotes prevents direct comparison of the speeds I recorded with the speeds reported by other authors.

Sperry (1939) reported that diets of "peg-leg" coyotes were similar to those of uninjured coyotes, although the "peg-leg" animals tended to consume more carrion and livestock. Except for jackrabbits (*Lepus* spp.) and ungulates, common prey species of coyotes reportedly are not capable of speeds more than 16.1 kph (Cottam and Williams, 1943). From my data, it appears that coyotes handicapped by the loss of a front foot are able to move faster than most of their prey species. Some loss of agility may account for the reported decrease in consumption of rodents by crippled coyotes (Sperry, 1939).

Acknowledgments

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Effects of Gamma Radiation and Temperature on Growth of Juvenile Rainbow Trout (Salmo gairdneri)

Abstract

Effects of gamma radiation and temperature on growth of juvenile rainbow trout (*Salmo gairdneri*) were studied in continuous flow aquaria. Fish fingerlings acclimated to 10°C were exposed to various doses of gamma radiation up to 1,000 RADS and placed into filtered tap water at 10°, 15°, and 20°C. They were reared in one of these water temperatures for four weeks and fed 4 percent of their body weight in commercial fish food once per day. Survivors were weighed weekly and counted daily in the basic experiment.

There were no statistically significant ($P < .05$) effects of temperature, radiation, or temperature-radiation interaction on growth. I concluded that the combined action of gamma radiation less than 1,000 RADS and temperature regimes studied did not noticeably affect growth of juvenile rainbow trout within the first four weeks.

Introduction

The objective was to determine the effects of a sublethal dose of gamma radiation and a sublethal temperature shock upon growth of juvenile rainbow trout (*Salmo gairdneri*). Primary emphasis was on the possible synergistic effects of these two variables.

Many studies on effects of radiation and temperature on fish have been published (for example, Gros *et al.,* 1958; Egami *et al.,* 1967; Etoh and Egami, 1967; Egami, 1969). None of these include the combined effects from sublethal doses of gamma radiation and a temperature shock.

Methods and Materials

Juvenile rainbow trout (*Salmo gairdneri*) were obtained from Troutlodge Springs Fish Hatchery near Soap Lake, Washington. Initial range of lengths and weights for the various replicates was variable (Table 1). Hatchery incubation temperature for all test fish was 10°C, and the total hardness (as $CaCO_3$) of the hatchery water was 120 ppm.

TABLE 1. Range of initial lengths and weights of juvenile rainbow trout (*Salmo gairdneri*).

Replicate	Date of Purchase	Length[a] (mm)	Weight (gms)
1	October 20	52-89	1.4-8.4
2	November 27	34-55	0.2-1.7
3	January 15	58-83	1.1-6.5
4	February 16	65-92	2.0-9.3

[a] The largest fish in any one test container within a trough was initially no longer than 1 1/2 times the shortest. All fish were of 0 age group, *i.e.,* less than 1 year old.

Continuous flow bioassay was used as the test procedure (Edmundson, 1971). Minimum water flow was 5 L/gm of fish per day. A hardness of 160 ppm, D. O. con-

centration from 8 to 10 ppm, pH of 7.5, and a copper concentration of 0.008 ppm or less were measured in the test water.

Each group, consisting of 10 fish each, was exposed to a 17,000 $Ci^{60}Co$ source at 10 or 11 R/sec to obtain approximate whole body acute gamma radiation doses of either 0, 320, 560, 870, or 1,000 RADS. Water temperature prior to and during radiation was 10°C. All radiation exposures were done between 3:30 and 5:00 pm. Within 30 sec after irradiation, I placed the fish into a test chamber containing either 10°, 15°, or 20°C water. Therefore, fish placed in 15°C water received an immediate temperature change of 5°C and those placed in 20°C received a change of 10°C. Fish were left in these temperatures and test containers for the remainder of the four-week experiment. Hereafter, I will refer to those fish that received 0°, 5°, or 10°C temperature change as 10°, 15°, and 20°C fish, respectively. Control fish were treated the same as irradiated fish, except they received no radiation. Fish were fed their hatchery diet of Sterling Silver Cup Fish Food No. 4 in amounts approximately 4 percent of their body wet weight once per day. Initially, the largest fish in a test container was no larger than 1 1/2 times the smallest. Once a week, I anesthetized (using MS 222), measured, and weighed individual fish in each group in the same manner as during initial measuring and weighing.

During all four replicates, all fish were swimming upright before being exposed to gamma radiation and before temperature changes. For further details concerning the procedure see Edmundson (1971).

All experiments were carried out at the Washington State University Nuclear Radiation Center, Pullman, Washington, during October 1970 to March 1971.

Results

The growth of juvenile rainbow trout was analyzed in two ways: (1) a separate analysis of variance of the average gain or loss in weight each week, and (2) an analysis of variance of the average total gain or loss in weight over the four-week period. Average weights of the fish present in a group were used because some fish died before the experiment was complete, thus complicating the analysis of variance. Weight gained or lost during the first week was computed as the average weight at the end of the first week minus the average initial weight of the group. Weight change for the second week was found by subtracting the average for the end of the second week from that for the end of the first week, and so forth. In referring to particular weeks, I will use week 1, 2, 3, or 4 to indicate the growth during the ith week ($i = 1, 2, 3, 4$). The reason for weekly comparisons is that fish which received a certain temperature-radiation combination may show a different functional response through time with the endpoints being similar. As observations among weeks were correlated (*i.e.,* they were the same fish for each group), statistical analysis of growth as a function of time and a single analysis of variance of the set of data were not attempted.

There were no statistically significant ($P < .05$) effects of temperature, radiation, or temperature-radiation interaction observed in any of the analyses (Table 2). Those fish raised in 15° and 20°C water (a temperature change of 5° or 10°C, respectively) averaged over all radiation levels, lost more weight on the average during week 1 than did the 10°C fish, but gained more during the remaining three weeks. Fish in 15°C water increased in final gained weight whereas those in 20°C gained only enough to

TABLE 2. Analysis of variance of the average gain or loss in weight (gm) of juvenile rainbow trout (*Salmo gairdneri*) exposed to acute gamma radiation and a temperature change.

Source of Variation	df	Week 1		2		3		4		Total	
		ms	F	ms	F	ms	F	ms	F	ms	F
Main Plot											
Replicates	3	1.449		.575		.586		.607		10.065	
Temperature[a]	2	.154	2.52	.043	2.69	.375	3.04	.282	4.82	1.018	2.12
Main plot error	6	.061		.016		.123		.066		.479	
Subplot											
Radiation[b]	4	.055	2.58	.028	1.41	.040	1.46	.065	1.23	.288	1.86
Radiation x temperature	8	.014	.64	.032	1.63	.008	.29	.052	.99	.086	.70
Subplot error	36	.021		.020		.027		.053		.122	
Total	59										
	$F\ .05^{(1,6)} = 5.99$					$F\ .05^{(4,36)} = 2.63$					
	$F\ .05^{(2,6)} = 5.14$					$F\ .05^{(8,36)} = 2.21$					

[a] Prior to and during irradiation fish were in 10°C water. After irradiation they were placed in 10°, 15°, or 20°C water for the remainder of the experiment (28 days).

[b] Whole body acute gamma radiation levels of 0, 320, 560, 870, and 1,000 R.

replace that amount lost during the four weeks. Largest average growth, ± one standard deviation, (0.38±0.69 gm) was observed in fish exposed to 15°C water and 320 RADS (Table 3). Lowest average growth was in 10°C fish exposed to either 0 (−0.37 ± 1.23 gm) or 870 RADS (−0.38 ± 1.16 gm). When I considered the average weekly or total growth combining all three temperatures, I found the growth pattern was similar at the different radiation levels. The synergistic relationship of temperature change and acute gamma radiation on average weekly growth and average total growth was not consistent.

TABLE 3. Average total gain or loss (± one standard deviation) in weight (gm) of juvenile rainbow trout (*Salmo gairdneri*) exposed to acute gamma radiation and a temperature change.

Radiation (RADS)	Temperature (°C)[a] 10°	15°	20°	Total
	$\bar{x} \pm s$[b]	$\bar{x} \pm s$	$\bar{x} \pm s$	$\bar{x} \pm s$
0	−0.37[c] ± 1.23	0.27 ± 0.68	0.14 ± 0.70	0.01 ± 0.87
320	−0.14 ± 1.42	0.38 ± 0.69	−0.03 ± 0.65	0.07 ± 0.88
560	0.02 ± 0.55	0.27 ± 0.76	0.23 ± 0.79	0.17 ± 0.65
870	−0.38 ± 1.16	0.10 ± 0.85	−0.31 ± 1.06	−0.20 ± 0.96
1000	−0.29 ± 0.96	0.05 ± 1.06	0.20 ± 0.98	−0.01 ± 1.03
Total	−0.23 ± 0.96	0.21 ± 0.74	0.04 ± 0.75	0.01 ± 1.03

[a] Prior to and during irradiation fish were in 10°C water. After irradiation they were placed in 10°, 15°, or 20°C water for the remainder of the experiment (28 days).

[b] Standard deviations were computed using the individual average total gain or loss in weight for each of the four replicates.

[c] Sample size was 40 fish (10 for each replicate) at the start of the experiment.

A comparison of the four replicates showed that average weekly growth pattern for each succeeding replicate was lower than the preceding replicate. Here again may be evidence that experimental control was influenced by the fish allocated to the replicates. However, all fish were gaining weight at the end of the four weeks.

Discussion

The effect of an abrupt 10°C or less temperature change on fish growth was not statistically apparent during the 28 days of this study. No differences were found which could not be explained by the temperature the animal was kept in or the feeding level. Although apparent trends were developing, 28 days did not give adequate time for the effect of combined temperature and radiation to show up.

There was considerable variation in the average growth observed in this experiment. A large amount of this variation apparently can be attributed to the difference in fish size among replicates. The weekly average growth declined during each consecutive replicate, with the lowest in the February-March replicate (replicate 4). At the end of the experiment, however, the fish were gaining weight in all replicates. Decrease in weight may be correlated with the time of first feeding within a replicate. The presence of fecal matter was used as an indication of feeding to see if such a relationship existed. In the first replicate, fecal matter began appearing on the fifth day, in replicates 2 and 3, within the tenth to fourteenth day, and in replicate 4, it was on the sixteenth day. Initial feeding of 10°C fish was usually one to two days after that of the 15° and 20°C fish. This delay in initial feeding time suggests that the physiological condition may not have been the same for the four groups of fish.

To my knowledge, the interaction of an immediate temperature change and radiation on growth of fish has not been reported. Effects of radiation on fish growth have been studied, but usually at varying temperatures. Bonham *et al.* (1948) stated that the effect of X-radiation on the growth of chinook salmon fingerlings during 12 weeks was generally directly related to the amount of X-rays received. The average weight of fish exposed to 250 R or less was not statistically different from the controls ($P \leq .05$), whereas groups receiving 500 R or more weighed less and the difference increased after four weeks. Welander *et al.* (1948) stated that differences in average weights of chinook salmon egged fry exposed to X-rays of 1,000 R were "doubtfully different" from O R through the sixty-fifth day. After 125 days, those salmon exposed to 1,000 R weighed 45 percent less than controls. No significant differences were observed in the final average weights of fish exposed to 500 R or less when compared to controls.

Yearling rainbow trout fed 0.5 uCi of Strontium-90-Yittium-90 per gram of tissue per day began to weigh less on the average after 12 weeks, as compared to controls; however, there was no statistical difference from the controls in those fed 0.05 uCi (Nakatani and Foster, 1963). Purdom (1966) reports that exposure of 500 or 1,000 R of X-rays to six-week old guppies (*Lebistes reticulatus*) did not affect lengths of the fish during the following eight weeks. One disadvantage of a four-week test is that during experiments which serve to place considerable stress on the fish, long-term growth effects may not be detectable. There is evidence in the literature, however, that growth responses to temperature can appear within four weeks (Banks *et al.,* 1971; Brett *et al.,* 1969).

In my experiment, there were indications of possible growth stimulating effects of radiation and temperature. Although not statistically significant, fish which received

320 or 560 RADS had greater average final growth when compared with those of other radiation levels and controls. The highest final growth was 320 RADS in 15°C water. This figure does not seem uncommon, since 15°C is near the optimum temperature for rainbow trout (Garside and Tait, 1958).

I did find, however, that fish exposed to 10°C and 0 RADS had the lowest growth of any group. One would think that these "control" fish would at least maintain their present weight. Since these fish were treated exactly the same as the other test fish, I can only conclude that stress of handling had an adverse impact.

The presence of a somewhat higher growth and survival of animals at low radiation levels has been reported before (Lorenz *et al.,* 1954; Carlson *et al.,* 1957; Carlson and Jackson, 1959; Marshall, 1963; Atlan, 1968; Wadley and Welander, 1971). Further research should be conducted testing the impact of temperature change and sublethal radiation over longer periods of time and during different times of the year.

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Effects of Some Clearcutting Practices on Small-Mammal Populations in Western Oregon[1]

Abstract

Changes in small-mammal populations and vegetation on two clearcuttings and one uncut stand of 125-year-old Douglas-fir, *Pseudotsuga menziesii,* in the foothills of the Cascade Mountains in western Oregon were noted from 1964 to 1970. Mark-release-recapture methods were followed each summer on a monthly basis. In all, more than 3,630 small mammals of 23 species were caught during three years of live-trapping from 1968 to 1970. Five species comprised more than 90 percent of the total catch.

Logging and controlled slash burning profoundly affected habitats occupied by small mammals. Rapid changes in plant abundance occurred in the unburned unit, and vegetative recovery was dominated by herbaceous annuals two years after clearcutting.

Shrews (*Sorex* sp) and chipmunks (*Eutamius* sp) were affected adversely by logging. Conversely, populations of deer mice (*Peromyscus* sp) and Oregon creeping voles *(Microtus oregoni)* were affected favorably by both logging and slash burning and increased in abundance after treatment on both clearcuttings.

Introduction

Timber harvesting affects small mammal populations because the production and survival of each species is dependent upon certain conditions of food and cover. In the past, wildfire was the most important natural factor that affected vegetative succession. In the Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) region of western Oregon, logging has become a major additional factor within the past century.

Knowledge as to how these populations are affected is important from several aspects. The forest manager should be cognizant of the changes imposed by timber harvesting upon all wildlife, not just big game animals. Secondly, the dependence of certain animal species upon specific types or conditions of vegetation may influence the utilization of animal-control measures based upon habitat management. Certain species possibly could be regulated by knowing the habitat requirements as well as the population densities of that species at different periods of vegetation development. Depending upon the condition of the habitat, changes may be required to develop or maintain vegetative associations. Disturbance usually returns vegetation to an earlier stage of plant succession, with the effect upon succession depending upon the kind and severity of the disturbance. Successful handling of wildlife populations conceivably could be possible through controlled burning, herbicides, or other tools available to the land manager.

Although studies of the effects of habitat changes on small mammals have been re-

[1] Paper No. 843, Forest Research Laboratory, School of Forestry, Oregon State University, Corvallis, Oregon 97331.

ported from other areas (Tevis, 1956; Cook, 1959; Ahlgren, 1966; Lawrence, 1966), few studies of this nature have been made in Oregon. Generally, past efforts were concerned primarily with the animal species thought to be most detrimental to forest regeneration (Moore, 1940, 1942; Hooven, 1953, 1958). Recently, more consideration is being given to interrelations within the biological community, such as in studies by Gashwiler (1959, 1970).

This work is concerned primarily with the forest biota and after clearcut logging of typical staggered settings. The objectives were to describe species of vegetation and small mammals and to follow the chronological changes of the communities of the three units studied. The effects of burning and nonburning of slash on the clearcuttings also were compared.

Study Area Description

The study area is located in eastern Lane County, Oregon, in the foothills of the western Cascade Range at T18S, R5E, Willamette Meridian (unsurveyed) in the Blue River Ranger District of the Willamette National Forest. The South fork of the McKenzie River drains about 208 square miles (539 km^2). It originates near the crest of the Cascade Mountains at about 6,000 ft (1,830 m) elevation. It flows westerly, then northerly, and falls about 3,000 ft. (914 m) in 15 miles (24.1 km) by the time it approaches the study area at Augusta Creek.

Topography is steep, and water runoff is rapid. The lavas of the older rocks are generally andesitic in character and range from rhyolite to basalt. The rhyolitic parent material weathers rapidly and, because of the humid temperature, produces a clayey soil.

The average annual precipitation of the area ranges from 60 to 80 inches (152 to 203 cm) in the foothills to over 120 inches (305 cm) at higher elevations. The extreme contrast between the mild, dry summers and wet winters is illustrated by 79 consecutive days without measurable rainfall on the study area during the summer of 1969 and 74 consecutive days with measurable precipitation during the winter of 1969-1970.

The forest vegetation before logging, as determined on Plot 1, the control plot, was composed of 32 species, dominated by Douglas-fir about 125 years old (Fig. 1), with a trace of western hemlock *(Tsuga heterophylla),* redcedar *(Thuja plicata),* sugar pine *(Pinus lambertiana),* and grand fir *(Abies grandis).* The area was site II for Douglas-fir, and the volume of the standing timber was 65 M fbm per acre. The age of the trees indicated that a major fire had swept through the area about 1850.

The understory vegetation was dominated by vine maple *(Acer circinatum)* and rhododendron *(Rhododendron macrophyllum).* Basal diameter of over 3.5 inches (8.9 cm) was common for the vine maple, and both it and the rhododendron had growth rings that indicated an age greater than 60 years. Salal *(Gaultheria shallon)* and Oregon-grape *(Berberis nervosa)* grew profusely where not shaded out by vine maple.

Methods

Three plots were established for study (Fig. 2). Plot 1 (untreated control) and Plot 2 (Loon Creek Sale) were originally part of the same forest, but were separated by a distance of 330 ft. (100.6 m).

Figure 1. Forested study area. Timber was 125-year-old Douglas-fir. Understory was mostly vine maple, rhododendron, salal, and Oregon grape.

Plot 2 was established on what became a clearcut timber sale (A131) of 41 acres (16.6 h). All timber was felled and removed by the highlead method by April 1968. Only the logging debris concentrated at two loading sites was burned. The aspect was easterly with a slope of about 25 degrees. A small brook flowed through the southern edge about 460 ft. (140 m) from the timber edge.

Plot 3 was established in 1967 on a clearcutting (A201) of 35 acres (14.9 h) that had been logged and the slashings removed by controlled burning in September

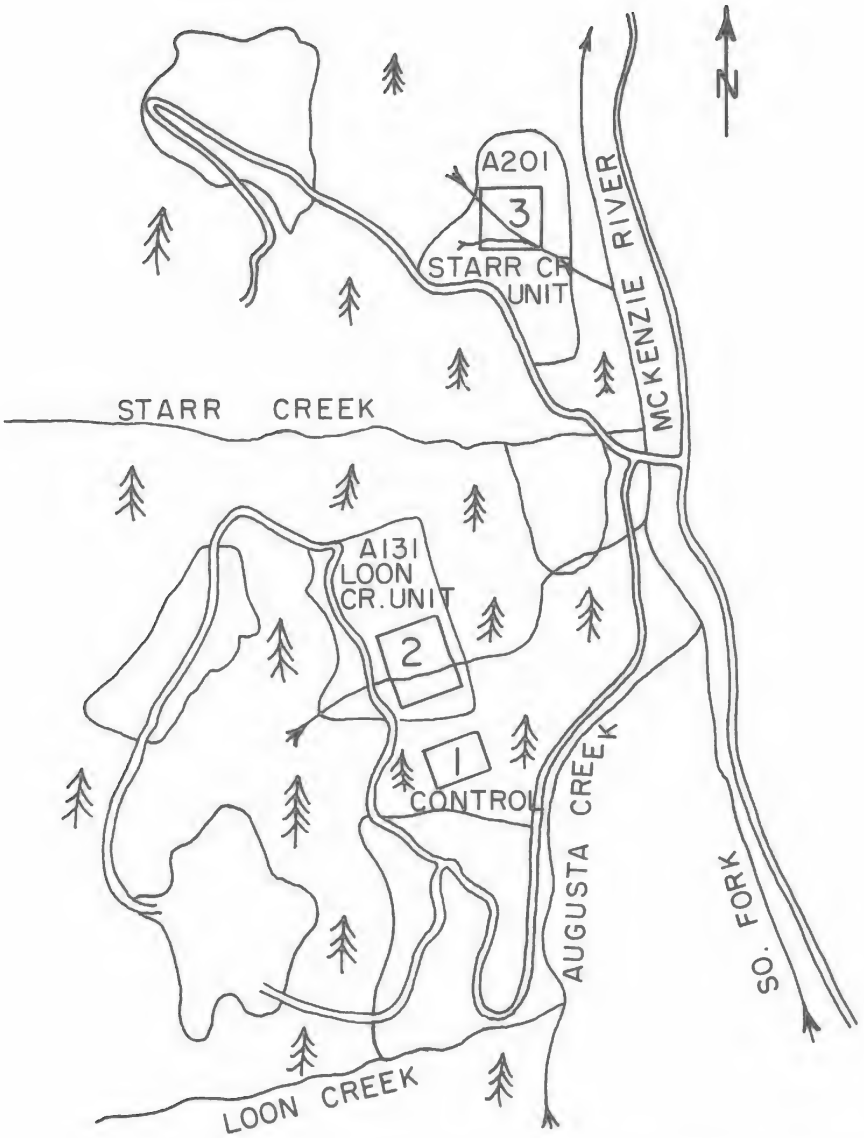

Figure 2. Location of study areas in the Blue River Ranger District of the Willamette National Forest.

1964. It was located one mile (1.6 km) north of plot 2 in the same forest. The area was flat, but dissected by a small brook.

Permanent live-trapping grids of 10 rows each at 66-ft (20 m) intervals were established on each area. Plot 1 contained five stations per row for a total of 50 stations in a rectangular grid of five acres (2 h). Plots 2 and 3 each contained 10 stations

per row for a total of 100 stations in a square grid of 10 acres (4 h). Two Sherman-type metal live traps of 22-gauge steel, 3.5 x 3.5 x 10 inches (9 x 9 x 25 cm), were set at each station. Covered cubbies of bark and limbs were made at each trapsite to protect trapped animals from exposure to the sun and rain. In addition, large, welded-wire live-traps 9 x 9 x 32 inches (23 x 23 x 81 cm) were set at 100-ft (30.5 m) intervals along each row.

Traps were set for three consecutive days a month from April to October, 1968-1970. Bait for small animals consisted of a mixture of whole rolled oats, Douglas-fir seed, and commercial birdseed. The large traps were baited with apples.

All small mammals, except the insectivores, were marked with a numbered metal ear-tag when first captured. Data were recorded for all animals by station number, species, ear-tag number, sex, age, condition, and reproductive condition when possible. All live animals were released where caught.

Subplots were established for the vegetation analysis. Alternate trapping stations were utilized by offsetting five feet from each station to locate the center of a one-milacre plot. Plants on each sampling plot were recorded by species and percentage of cover. Cover-class estimates were rated on a scale of 1 to 5, where 1 equals 1 to 20 percent, 2 equals 21 to 40 percent, 3 equals 41 to 60 percent, 4 equals 61 to 80 percent, and 5 equals 81 to 100 percent ground cover.

Results

Plot 1, Control

Vegetation on Plot 1 consisted of six tree species, seven shrubs, and 19 herbs, ferns, and grasses (Table 1).

Plot 2, Unburned Slash

Soil disturbance on Plot 2 was less than 40 percent after logging. All logs were removed uphill by high-lead to the landings. Disturbance was severe only where the skid tracks converged to the landings. This disturbance exerted a major influence on the vegetation and its recovery for several years after logging was completed. Although all of the vegetation had been damaged or uprooted by skidding logs, few invading plants were noted during sampling in 1968. The 36 species tallied were mostly remnants of plants that had survived logging.

Crown cover of the understory species was greatly reduced, as most of the stems had been damaged. Vine maple, which had formed arches from 10 to 12 ft. (3.0-3.7 m) tall under the standing timber, was reduced to barked stubs, and the brittle rhododendron had been broken off at the ground level. Both species, however, began to sprout from root collars by midsummer.

Small perennials also had been disturbed severely and appeared as low sprouts from roots. Logging, however, had little effect upon the frequency of salal, Oregon-grape, trailing blackberry *(Rubus ursinus)* or sword fern*(Polystichum munitum).* Thimbleberry *(Rubus parviflorus)* apparently was benefitted by the decrease of competition, because it became a rapid invader of the area. New Zealand fireweed *(Erechtites arguta),* a rapid and common invader of bare soil, was prevalent by late summer.

We found other differences in vegetative composition attributable to topographic differences and to the influence of the adjacent timber. The area south of the stream

TABLE 1. Plant species by frequency and cover on the study areas, 1968-1970.

Species	Loon Creek Sale								Starr Creek Sale					
	Frequency				Cover[3]				Frequency			Cover[3]		
	1964[1]	1968	1969	1970	1964[1]	1968	1969	1970	1968	1969	1970	1968	1969	1970
Abies grandis	0[2]	—	—	—	—	—	—	—	—	—	—	—	—	—
Acer circinatum	92	64	70	52	3	1	2	2	16	20	20	2	3	3
Acer macrophyllum	—	0	—	—	—	—	—	—	—	—	—	—	—	—
Achlys triphylla	2	—	2	—	1	—	1	—	—	2	—	—	1	—
Adenocaulon bicolor	—	—	—	0	—	—	—	—	10	4	2	1	1	1
Agoseris aurantiaca	—	—	—	—	—	—	—	—	—	—	10	—	—	2
Agoseris glauca	—	—	—	—	—	—	—	—	48	0	—	1	—	—
Agoseris heterphylla	—	—	—	0	—	—	—	—	0	—	0	—	—	—
Agrostis sp.	—	—	—	—	—	—	—	—	2	—	—	1	—	—
Alnus oregana	0	—	—	—	—	—	—	—	—	—	—	—	—	—
Amelanchier florida	—	2	—	—	—	1	—	—	—	—	—	—	—	—
Amelanchier pallida	—	0	—	—	—	—	—	—	—	—	—	—	—	—
Anaphalis margaritacea	—	—	8	0	—	—	1	—	6	84	4	1	2	2
Anemone deltoidea	—	—	—	—	—	—	—	—	12	0	—	1	—	—
Anemone lyallii	—	—	—	—	—	—	—	—	—	—	2	—	—	3
Aralia californica	—	—	—	—	—	—	—	—	0	—	—	—	—	—
Arctostaphylos columbiana	—	—	—	2	—	—	—	1	14	10	8	1	1	3
Asarum caudatum	4	0	—	—	1	—	—	—	—	—	—	—	—	—
Athyrium felix-femina	2	—	—	—	1	—	—	—	2	—	—	1	—	—
Berberis nervosa	96	84	84	72	2	1	2	1	69	68	66	1	2	1
Boykinia elata	—	2	—	2	—	1	—	2	4	—	—	1	—	—
Campanula scouleri	—	—	—	—	—	—	—	—	36	10	10	1	1	1
Carex sp.	—	10	—	2	—	1	—	2	6	—	4	1	—	2
Castanopsis chrysophylla	—	—	—	—	—	—	—	—	10	10	6	1	1	2
Ceanothus integerrimus	—	—	—	—	—	—	—	—	2	—	—	1	—	—
Ceanothus sanguineus	—	0	20	—	—	1	1	1	38	38	38	1	1	2
Centaurea cyanus	—	—	—	—	—	—	—	—	0	—	—	—	—	—
Cerastium glomeratum	—	—	—	—	—	—	—	—	—	—	2	—	—	2
Chenopodiaceae spp.	—	0	—	—	—	—	—	—	—	—	—	—	—	—
Chimaphila menziesii	12	—	—	—	1	—	—	—	—	—	—	—	—	—
Chrysanthemum leucanthemum	—	—	0	—	—	—	—	—	—	—	0	—	—	—
Circaea pacifica	2	4	—	2	1	1	—	1	—	—	—	—	—	—
Cirsium arvense	—	—	2	5	—	—	1	1	10	10	—	1	1	—
Cirsium vulgare	—	2	8	5	—	1	1	1	72	46	34	1	1	1
Collomia heterophylla	—	—	—	—	—	—	—	—	2	—	14	1	—	1
Conyza canadensis	—	—	—	10	—	—	—	1	82	12	20	1	1	2

TABLE 1. (Continued)

Species	Loon Creek Sale								Starr Creek Sale					
	Frequency				Cover[3]				Frequency			Cover[3]		
	1964[1]	1968	1969	1970	1964[1]	1968	1969	1970	1968	1969	1970	1968	1969	1970
Coptis laciniata	20	4	—	—	1	1	—	—	6	—	—	1	—	—
Cornus nuttallii	—	—	—	0	—	—	—	—	2	10	10	1	2	1
Corylus cornuta	6	4	4	6	1	1	1	1	0	2	0	—	1	—
Crepis capillaris	—	—	—	0	—	—	—	—	0	—	0	—	—	—
Crepis setosa	—	—	2	4	—	—	1	1	—	36	12	—	1	1
Deschampsia elongata	—	—	4	—	—	—	1	—	—	4	—	—	1	—
Epilobium adenocaulon	—	0	—	—	—	—	—	—	—	—	—	—	—	—
Epilobium angustifolium	—	6	16	—	1	1	3	1	50	48	1	2	1	—
Epilobium paniculatum	—	16	4	76	—	1	1	2	60	18	54	1	1	2
Epilobium watsonii	—	—	40	64	—	—	2	1	96	72	38	1	2	1
Equisetum arvense	—	—	—	—	—	—	—	—	4	12	10	1	1	1
Erechtites arguta	—	34	—	—	—	1	—	—	2	—	—	1	—	—
Festuca occidentalis	—	—	—	—	—	—	—	—	18	—	—	1	—	—
Fragaria vesca	—	—	—	0	—	—	—	—	—	—	4	—	—	1
Galium aparine	—	—	—	6	—	—	—	1	—	—	4	—	—	1
Galium boreale	—	—	—	2	—	—	—	1	—	—	—	—	—	—
Galium oreganum	4	—	—	2	1	—	—	2	—	—	4	—	—	1
Galium triflorum	10	10	14	6	1	1	2	1	18	18	2	1	2	1
Garrya fremontii	—	—	—	—	—	—	—	—	0	—	—	—	—	—
Gaultheria shallon	54	56	56	40	2	1	2	2	50	48	30	1	2	1
Gnaphalium japonicum	—	—	—	—	—	—	—	—	11	6	—	1	1	—
Gnaphalium microcephalum	—	—	—	—	—	—	—	—	22	—	—	1	—	—
Gnaphalium purpureum	—	—	—	2	—	—	—	1	11	22	30	1	1	1
Goodyera oblongifolia	8	—	—	—	1	—	—	—	—	—	—	—	—	—
Gramineae spp.	—	10	10	6	—	1	1	1	24	36	16	7	1	2
Hieracium albiflorum	—	4	—	16	—	1	—	2	30	2	18	1	1	1
Holodiscus discolor	—	—	—	4	—	—	—	2	—	—	—	—	—	—
Hypochaeris radicata	—	—	—	2	—	—	—	1	0	20	40	—	1	1
Iris tenax	—	—	—	2	—	—	—	3	—	—	2	—	—	1
Juncaceae spp.	—	—	—	—	—	—	—	—	4	2	4	1	2	1
Lactuca scariola	—	4	—	10	—	1	—	1	94	2	0	1	1	—
Lilium washingtonianum	—	—	—	—	—	—	—	—	2	0	0	—	—	—
Linaria vulgaris	—	—	—	—	—	—	—	—	0	—	—	—	—	—
Linnaea borealis	—	—	—	0	—	—	—	—	10	—	0	1	—	—
Listera caurina	18	—	—	—	1	—	—	—	—	—	—	—	—	—
Lolium perenne	—	—	2	—	—	—	1	—	—	22	—	—	3	—

TABLE 1. (Continued)

Species	Loon Creek Sale								Starr Creek Sale					
	Frequency				Cover[3]				Frequency			Cover[3]		
	1964[1]	1968	1969	1970	1964[1]	1968	1969	1970	1968	1969	1970	1968	1969	1970
Lonicera ciliosa	—	—	—	—	—	—	—	—	0	—	—	—	—	—
Lotus crassifolius	—	—	—	—	—	—	—	—	30	36	32	2	3	2
Lupinus latifolius	—	—	—	—	—	—	—	—	22	20	26	1	2	1
Luzula sp.	—	—	—	—	—	—	—	—	26	—	—	1	—	—
Lysichitum americanum	—	—	—	—	—	—	—	—	—	—	0	—	—	—
Madia sativa	—	—	—	0	—	—	—	—	2	4	26	1	1	1
Mimulus sp.	—	—	—	—	—	—	—	—	2	—	—	1	—	—
Mitella sp.	—	2	—	—	—	1	—	—	0	—	—	—	—	—
Monotropa uniflora	4	—	—	—	1	—	—	—	—	—	—	—	—	—
Montia perfoliata	—	—	—	—	—	—	—	—	—	2	—	—	1	—
Montia sibirica	—	4	—	4	—	1	—	1	—	4	—	—	1	—
Nemophila parviflora	—	—	—	2	—	—	—	1	—	—	—	—	—	—
Petasites speciosa	—	0	—	—	—	—	—	—	—	—	—	—	—	—
Phacelia sp.	—	—	—	—	—	—	—	—	0	—	—	—	—	—
Pinus lambertiana	0	—	—	—	—	—	—	—	—	—	—	—	—	—
Polystichum munitum	26	18	20	12	1	1	2	1	4	6	2	1	2	1
Populus trichocarpa	—	—	—	—	—	—	—	—	—	—	0	—	—	—
Prunus emarginata	—	—	—	—	—	—	—	—	0	0	0	—	—	—
Pseudotsuga menziesii	16	—	2	6	—	—	1	1	18	26	10	1	1	1
Pteridium aquilinum	8	10	10	10	1	1	2	1	46	44	38	1	3	2
Rhamnus purshiana	6	8	10	10	1	1	1	3	0	4	4	—	1	1
Rhododendron macrophyllum	12	6	6	6	1	1	1	2	16	16	22	1	2	2
Ribes lobbii	—	—	—	—	—	—	—	—	0	—	—	—	—	—
Ribes sanguineum	—	—	—	—	—	—	—	—	6	0	2	1	—	1
Rosa gymnocarpa	—	—	—	—	—	—	—	—	2	62	1	1	2	
Rubus laciniatus	—	—	—	0	—	—	—	—	—	—	0	—	—	—
Rubus leucodermis	—	—	2	0	—	—	1	—	6	6	6	1	3	1
Rubus parviflorus	2	44	44	32	1	1	1	2	38	40	22	1	2	3
Rubus spectabilis	—	—	4	—	—	—	2	—	—	4	—	—	1	—
Rubus ursinus	30	48	46	56	1	1	2	2	86	78	1	3	3	2
Salix sp.	—	—	—	0	—	—	—	—	4	2	0	1	1	—
Sambucus glauca	—	—	—	—	—	—	—	—	4	0	0	1	—	—
Sanicula crassicaulis	—	—	—	—	—	—	—	—	2	—	—	1	—	—
Saxifraga mertensiana	2	—	—	—	1	—	—	—	—	—	—	—	—	—
Senecio sylvaticus	—	—	—	20	—	—	—	1	—	—	—	—	—	—
Senecio vulgaris	—	—	72	40	—	—	1	1	—	2	12	—	1	1

TABLE 1. (Continued)

Species	Loon Creek Sale								Starr Creek Sale					
	Frequency				Cover[3]				Frequency			Cover[3]		
	1964[1]	1968	1969	1970	1964[1]	1968	1969	1970	1968	1969	1970	1968	1969	1970
Smilacina sessilifolia	—	—	—	—	—	—	—	—	—	—	0	—	—	—
Sonchus asper	—	—	—	10	—	—	—	1	2	10	—	1	1	—
Sonchus oleraceus	—	—	—	10	—	—	—	1	—	6	—	—	1	—
Stachys ciliata	—	—	—	—	—	—	—	—	2	—	—	1	—	—
Stachys rigida	—	—	—	—	—	—	—	—	—	12	0	—	1	—
Stellaria borealis	—	—	—	—	—	—	—	—	—	—	2	—	—	1
Symphoricarpos albus	—	2	—	—	—	1	—	—	0	—	—	—	—	—
Taraxacum officinale	—	—	4	—	—	—	1	—	—	32	8	—	1	1
Tellima grandiflora	—	—	—	2	—	—	—	1	—	—	—	—	—	—
Tiarella unifoliata	8	—	2	—	1	—	1	—	12	10	2	1	1	1
Trientalis latifolia	2	2	6	20	1	1	1	1	60	54	52	1	1	1
Trillium ovatum	6	—	—	0	1	—	—	—	0	0	4	—	—	1
Tsuga heterophylla	—	0	—	—	—	—	—	—	—	—	—	—	—	—
Typha latifolia	—	—	—	—	—	—	—	—	—	2	—	—	4	—
Vaccinium parvifolium	2	—	—	—	1	—	—	—	2	6	2	1	1	1
Vaccinium ovatum	—	—	—	—	—	—	—	—	—	8	—	—	1	—
Vancouveria hexandra	2	2	—	—	1	1	—	—	2	—	2	1	—	1
Vicia americana	—	—	—	—	—	—	—	—	—	—	2	—	—	1
Viola nuttallii	—	—	—	—	—	—	—	—	—	2	—	—	1	—
Viola sempervirens	8	—	—	—	1	—	—	—	36	14	22	1	1	1
Whipplea modesta	—	—	—	—	—	—	—	—	0	6	—	—	2	—

[1] Data from Loon Creek Control in 1964, assuming no change to 1970.
[2] Species found on unit, but not found on any of the plots.
[3] Cover class estimates are rated from 1 to 5, where 1 equals 1-20%, 2 equals 21-40%, 3 equals 41-60%, 4 equals 61-80%, and 5 equals 81-100% gro
cover.

had a northerly aspect and also was shaded by the adjacent timber. Most of the sword fern, thimbleberry, bedstraw *(Galium triflorum),* and miner's lettuce *(Montia perfoliata)* occurred on this protected area. Conversely, the willow-herbs *(Epilobium* sp*),* buck brush *(Ceanothus sanguineus),* and manzanita *(Arctostaphylos columbiana)* first appeared on the more disturbed, drier and warmer southern exposures north of the stream. The ceanothus and manzanita developed from seeds that had lain dormant in the forest and had germinated after exposure to increased light and temperature (Lyon, 1966).

A year after logging, in 1969, 30 plant species were recorded. Many species native to the undisturbed stand showed an increase in size but their frequency was unchanged. Vine maple sprouts grew 2 to 3 feet (0.6 to 0.9 m) (Fig. 3) and, like the rhododendron, were much bushier. Species that had been of low occurrence became more common. These included groundsel *(Senecio vulgaris),* Pacific willow-herb *(Epilobium watsoni),* tall willow-herb *(Epilobium paniculatum),* fireweed willow-herb *(Epilobium angustifolium),* thistles *(Cirsium* sp*),* and pearly everlasting *(Anaphalis margaritacea).*

Figure 3. Plot 2, with vegetative development 2 years after logging. Note spreading form of hardwood shrubs, principally vine maple, rhododendron, hazel, and dogwood.

A tremendous increase in vegetative density and cover occurred in 1970, the second summer after logging. The vegetative survey recorded 53 plant species. The entire area, excepting the skidroads, was covered densely by annual and perennial plants. Vine maple had grown to 8 to 10 ft (2.4-3.0 m) tall and formed dense clumps that prevented the development of other plants in their shade. Rhododendron and hazel (*Corylus cornuta)* also became bushier, and trailing blackberry, bedstraw, and starflower *(Trientalis latifolia)* continued to increase in abundance. Sowthistle *(Sonchus* sp*)* and hawkweed *(Hieracium albiflorum)* appeared to be replacing the common thistles. Of the invading species, willow-herbs increased most. They were dense over most of the area except where shaded by the more aggressive shrubs. Groundsels became less abundant, pearly everlasting decreased to a trace, and New Zealand fireweed disappeared entirely. Woody shrubs, especially manzanita and ceanothus, became more common. Note that, although 75 different species were recorded for the three-year period, the yearly totals ranged from 36 to 30 to 53.

Plot 3, Slash-burned

Plot 3 (Fig. 4) had been logged in 1964 and the slashings burned that fall by a fire of moderate intensity. The smaller debris had been burned, but the larger cull material remained in moderate density. The initial vegetation survey in the summer of 1968 included 79 plant species: six trees, 16 shrubs, 52 herbs and ferns, and five grasses, sedges and rushes (Table 1).

Development of the vegetation was affected by the fire and variations of the intensity of burning. Many species developed as sprouts from root crowns. Vine maple, for example, was as common on Plot 3 before logging as it had been on Plot 2. Slash burning, however, had destroyed much of its aboveground parts and sharply reduced its frequency. It sprouted from exposed root crowns and developed into dense, compact bushes that were not as vigorous as those on the unburned unit. Chinquapin *(Castanopsis chrysophylla),* dogwood *(Cornus nuttallii),* hazel, and rhododendron developed in the same manner.

The principal herbaceous plants such as salal, Oregon-grape, and trailing blackberry were common over the entire unit. Blackberry was particularly stimulated by the burning, possibly through the lessening of vegetative competition. Manzanita and ceanothus also were common and widespread.

Numerous herbs with wind-borne seeds, which were invaders of bare or burned-over soil, still were well distributed over the unit four years after burning. These included the various willow-herbs, common thistle *(Cirsium vulgare),* Canada thistle *(Cirsium arvense),* cud weeds *(Gnaphalium* sp*),* prickly lettuce *(Lactuca scariola),* pearly everlasting, and lupine *(Lupinus latifolius).*

During the second examination, in 1969, the overall plant density continued to increase, but the number of species declined moderately compared to the previous year's observation. Common thistle, tall willow-herb, and starflower, which had developed abundantly after logging, began to decline in frequency; but the abundance of other species such as horseweed *(Conyza canadensis),* small-flowered willow-herb *(Epilobium minutum),* prickly lettuce, and hawkweed decreased sharply.

The examination during 1970 indicated about the same number of species (70), but a continuing change in frequency for some of them. Salal, trailing blackberry,

Figure 4. Plot 3 in the summer of 1970. The slash was burned in the fall of 1964. Note absence of shrubby clumps, compared to Plot 2, Fig. 3.

thimbleberry, and starflower decreased slightly in frequency, but willow-herbs decreased greatly. New Zealand fireweed was not recorded, and few groundsels were noted. Hairy cats-ear *(Hypochaeris radicata)* and tarweed *(Madia sativa)* increased sharply and appeared to be able to compete successfully with other herbs under adverse conditions.

Mammalia

Small mammals were live-trapped each summer on one or more of the three areas from June 1964 to September 1970. Twenty-three of the 30 mammalian species known to have been present on the areas were caught (Table 2). Not caught, but known to be present from their sign, sound, tracks, and scats, were pocket gophers *(Thomomys mazama),* coyotes *(Canis latrans),* bears *(Ursus americanus,)* raccoons *(Procyon lotor),* bobcats *(Lynx rufus),* elk *(Cervus canadensis),* and deer *(Odocoileus hemionus).*

Simultaneous comparisons of annual catches among the areas did not start until 1968, so data in this paper are confined to 1968-69-70. Remember that Plot 3, slash-burn, was four years older than Plots 1 and 2.

TABLE 2. Small mammals recorded on the three study plots during 1968, 1969, and 1970 showing annual catch and the species relationship to the plot-catch.

	Plot 1 Untreated 5 acres (2.0 ha)[1]				Plot 2 Clearcut Unburned 10 acres (4.0 ha)				Plot 3 Clearcut Burned 10 acres (4.0 ha)			
	1968	1969	1970	%	1968	1969	1970	%	1968	1969	1970	%
Sorex trowbridgii	88	124	108	25.0	67	97	50	19.8	28	68	34	10.1
Sorex vagrans	20	14	86	9.7	5	17	50	6.6	5	5	5	2.1
Sorex bendirii	—	—	—	—	—	1	—	—	2	0	1	0.2
Neurotrichus gibbsii	6	4	12	1.7	1	1	2	0.4	—	—	—	—
Scapanus orarius	1	0	0	—	2	0	0	—	0	1	0	—
Ochotoma princeps	1	0	0	—	—	—	—	—	—	—	—	—
Lepus americanus	16	12	10	3.0	0	0	1	—	—	—	—	—
Aplodontia rufa	—	—	—	—	0	0	1	—	—	—	—	—
Spermophilus beecheyi	—	—	—	—	—	—	—	—	8	0	0	0.6
Eutamias townsendii	156	114	38	24.1	30	99	34	15.0	99	146	37	21.8
Tamiasciurus douglasii	4	10	8	1.7	0	0	1	—	—	—	—	—
Glaucomys sabrinus	8	2	0	0.8	—	—	—	—	—	—	—	—
Peromyscus maniculatus	16	174	66	20.0	36	222	94	32.5	59	227	130	32.2
Neotoma cinerea	1	0	0	—	2	0	0	—	—	—	—	—
Clethrionomys californicus	74	8	8	7.0	3	0	0	—	—	—	—	—
Phenocomys albipes	1	0	0	—	0	0	2	—	—	—	—	—
Microtus oregoni	10	28	30	5.3	23	100	96	20.2	61	99	189	27.0
Microtus richardsoni	—	—	—	—	0	3	6	0.8	21	5	5	2.4
Zapus trinotatus	4	6	0	0.8	0	0	11	1.0	16	9	9	2.6
Erethizon dorsatum	1	0	0	—	0	0	0	—	—	—	—	—
Mustela erminea	4	2	4	0.8	2	1	3	0.5	3	4	2	0.7
Mustela frenata	—	—	—	—	—	—	—	—	1	0	0	—
Spilogale putorius	—	—	—	—	—	—	—	—	0	0	1	—
	411	498	370		171	541	351		303	564	425	
		1,279				1,063				1,292		
		3,634										

[1] The data from this 5-acre trapping grid have been adjusted (doubled) for comparison with the catches recorded on the larger 10-acre grids on the clearcut areas.

Insectivora

Four species of shrews were captured: *Sorex trowbridgii, S. vagrans, S. yaquinae,* and *S. bendirii.* Shrews comprised 24 percent of the total catch, with the Trowbridge shrew comprising 76 percent of all shrews caught. The shrews responded to the vegetational alteration, especially on Plot 3, where fire was an additional factor. During the three years, 48 percent of the catch of Trowbridge shrews was caught on the untreated control, 32 percent on the unburned clearcutting, and 20 percent on the slash-burned unit. The catch of vagrant shrews (60, 35, 7 percent) was similar to that of Trowbridge shrews on the three plots. So few *S. yaquinae* were caught that they were incorporated with the data of the vagrant shrew.

The marsh shrew *(S. bendirii)* was uncommon. None was caught before timber removal. After clearcutting, it was taken only in traps set adjacent to running water. Vegetative development, regardless of whether slash burning had occurred, seemed to favor its presence. The marsh shrew was first caught on Plot 3 three years after slash burning and on Plot 2 two years after logging. Because of the confinement of the range of the marsh shrew to water, it was believed to be more common than was revealed by the trap catches. Vegetation at the trapping stations where captures occurred was dense to the water's edge with sedge *(Carex* sp*),* hedge nettle *(Stachys mexicana),* horsetail *(Equisetum arvense),* rushes *(Juncus* spp*),* bulrush *(Scirpus microcarpus),* and grasses. Marshy areas on Plot 3 were larger, more pronounced, and appeared to have a more abundant aquatic population than on Plot 2.

Shrew-moles *(Neurotrichus gibbsii)* were caught infrequently (Table 2). *Neurotrichus* is considered a typical resident of dark, marshy, wooded areas (Dalquest, 1941), but is uncommon in dry woods or logged-over lands. We found that ground cover is important to the shrew-mole. The untreated area, with its undisturbed mat of decaying litter, had a larger population than did Plot 2, where logging debris only partially covered the area and about 45 percent of the ground was bare. Plot 3, which had fine slashings and little ground cover, yielded no shrew-moles.

The coast mole *(Scapanus orarius)* also was caught infrequently. Although uncommon, moles were caught on all three plots.

Lagomorpha

One pika *(Ochotona princeps)* was captured in the timber in July. The nearest known colony was a small one on a ½ acre (0.2 h) rocky area 1 mile (1.6 k) east of the study area.

Snowshoe hares *(Lepus americana)* were an important component of the fauna of the uncut timber, representing about 3 percent of the animals caught on Plot 1. One or more hares were caught nearly every trapping period, and density ranged from 0.2 to 1.6 hares per acre (0.4 h). Considering the apparent lack of food, the continued presence of at least several hares on Plot 1 was surprising. Hares did not repopulate the clearcuttings for the first few years after logging. The hares caught on Plot 2 before logging were not recaught when trapping was resumed after timber removal. A young hare was caught on Plot 2 in 1970, however, and clipped blackberry vines were noted on Plot 3. Removal of forest cover causes a sharp decline in hare density, but the number increase as vegetative cover increases. Hares become a problem to reforestation about 10 years after a fire. This was noted after the Tillamook Burn fire of 1945

in Northwest Oregon and also after a 2,200-acre fire in the western Cascade Mountains (Black, 1965), where more than five hares per acre were recorded.

Rodentia

The mountain beaver *(Aplodontia rufa)* is common in many areas of the western Cascade Mountains and Coast Range of Oregon. Although none occurred on the units before logging, a small colony was located near the east boundary of Plot 2 close to a small spring. The mountain beaver harvested primarily sword fern, vine maple, and rhododendron. The colony disappeared after Plot 2 was logged. The second summer after logging, sign of mountain beaver activity was noted along the stream of Plot 2 by the presence of burrowing and clipped shrubs. Harvested plants included bracken fern *(Pteridium aquilinum),* thimbleberry, hazel, trailing blackberry, and groundsel. The mountain beaver had disappeared, for unknown reasons, by the spring of 1970.

California ground squirrels or graydiggers *(Spermophilus beecheyi)* were caught only on Plot 3 and only during 1968. Eight were trapped and removed because of their continuous disturbance of the small-mammal traps. This was the only species removed. Graydiggers invade logged and burned-over areas during the early seral stages in western Oregon. They require large open areas of herbaceous vegetation and decline as the vegetation, especially the brush species, develop. Information about the graydigger's feeding habits on cutover lands is lacking, but at least part of their diet is the achenes of the common thistle which they harvest before seed dispersal, hazelnuts, and the fruit of elderberry *(Sambucus glauca).*

The flying squirrel *(Glaucomys sabrinus)* and the Douglas squirrel *(Tamiasciurus douglasii)* are chiefly arboreal and obviously were affected by removal of the timber. Neither species was considered rare in the control Plot 1, but tagged squirrels were rarely recaught. Neither bait, traps, nor trap placement could be considered suitable for catching arboreal animals.

A bushy-tailed woodrat *(Neotoma cinerea)* was caught on Plot 1 and two were captured on Plot 2. They were considered as casual dispersals as their preferred natural habitat includes rimrock cliffs and caves overgrown with vegetation.

A white-footed vole *(Arborimus albipes)* was caught on Plot 1 at the base of a large Douglas-fir (90 cm dbh) and several were caught on Plot 2 in traps set close to the stream. Little is known of the habitat preferences of this rare vole. Maser and Storm (1970) state that its macrohabitat is generally dense, moist, coniferous forest in association with riparian microhabitats.

Red-backed mice *(Clethrionomys californicus)* are recorded as living primarily in cool, damp forests (Townsend, 1935; Bailey, 1936), or are at least restricted to forest areas, although the cover may vary in density (McNab and Dirks, 1941; Williams, 1955). Removal of timber and reduction of vegetative cover on the clearcuttings reduced the suitability of the habitat for red-backed mice. The few individuals captured on Plot 2 were caught adjacent to the timber of Plot 1 and on a north exposure. This area was cooler than the rest of the clearcutting because it was partially shaded by trees. Dew also remained on the vegetation longer in the shaded area, which caused a humid, cooling effect that did not occur on the remainder of Plot 2 or on Plot 3. No red-backed mice were captured on the more open, drier areas. Feeding habits of the red-backed mice are mostly unknown. Bailey (1936) reported that they feed largely

on green vegetation, seeds, and grass. Trap-confined red-backed mice ate Douglas-fir seeds used as a bait component during the study.

The jumping mouse *(Zapus trinotatus)* is found throughout the Cascade Mountains in Oregon (Bailey, 1936). Most of the captures during this study occurred in traps near creeks, which agrees with the observations that jumping mice prefer damp, marshy places (Svihla and Svihla, 1933). Food of the jumping mouse consists mainly of small seeds of grasses and other plants obtained by cutting off the seed heads (Hamilton, 1935). It was the only species that readily utilized the commercial birdseed in the bait. *Zapus* also feeds on berries and fruits and may be highly insectivorous under natural conditions, as is *Z. hudsonius* (Dalquest, 1948). All of these foods were much more abundant on the clearcutting than in the forest.

The Townsend's chipmunk *(Eutamias townsendii)* was common on the three plots and comprised 20.7 percent of the small mammals caught. Chipmunk populations differed in density among plots (Table 3). Although population densities fluctuated annually, the total catch of chipmunks for the three years was slightly greater on Plot 1 than on Plot 3, and much greater than on Plot 2.

TABLE 3. Mean number of small mammals caught per acre per trapping period, and mean number of untagged animals caught per acre for each year from 1967 to 1970.

	Plot 1		Plot 2		Plot 3	
	Trapping Period	Year	Trapping Period	Year	Trapping Period	Year
1968						
Sorex	1.5	10.8	1.2	7.2	0.5	3.3
Eutamias	4.3	15.6	1.0	3.0	2.7	9.9
Peromyscus	0.3	1.6	1.1	3.6	1.6	5.9
Microtus	0.2	1.0	0.5	2.3	1.4	6.1
1969						
Sorex	2.0	13.8	1.6	10.4	1.0	7.3
Eutamias	2.8	11.4	2.5	9.9	3.8	14.6
Peromyscus	6.4	17.4	8.0	22.2	7.8	22.7
Microtus	0.7	2.8	2.3	10.0	2.2	9.9
1970						
Sorex	2.8	19.4	1.4	10.0	0.7	5.1
Eutamias	1.6	3.8	1.4	3.4	1.6	3.7
Peromyscus	2.5	6.6	2.8	9.4	4.0	13.0
Microtus	0.7	3.0	2.2	9.6	4.4	18.9

The diet of *E. townsendii* varies with the seasons and consists of seeds, nuts, fruits, fungi, and insects when available (Tevis, 1952). Chipmunks, on the clearcuttings, fed on ripening seed of the common thistle, as noted from piled remains of thistle achenes. Blackberries and western raspberries *(Rubus leucodermis)* were a major part of the diet when in season, as revealed by discoloration of the animal's mouth parts and remains of berries found in fecal material left in the live-traps. Chipmunks confined in live-traps consistently selected the Douglas-fir seeds of the bait. After filling their cheek pouches, they often piled excess seeds neatly in a corner of the trap as though they were attempting to cache them.

White-footed deer mice, the most abundant species, represented 28 percent of the

small-mammal catch. Their numbers varied among the study units, the greatest number being caught on the slash-burned Plot 3 (Table 2). The catch of deer mice on Plot 3 was 62 percent greater than on the control plot and 27 percent greater than on Plot 2. Differences in density by trapping periods also appeared greater on the clearcuttings (Table 3).

Deer mice are omnivorous. They feed preferably on seeds, grains, and berries when these are available. *Peromyscus* also feed readily on insects (Cogshall, 1928), and Tevis found them in stomachs of 90 percent of deer mice examined from both logged and unlogged forest lands. (Tevis, 1956). *Peromyscus* preferred the Douglas-fir seed in our bait mixture. Yearly fluctuations in population of deer mice are thought to be related to the production of Douglas-fir seed. Few deer mice were caught in 1968, but they increased sharply in 1969, which was a peak year for production of Douglas-fir seed, the seed being abundantly available during fall and winter. But herbaceous plants, notably the willow-herbs and berries, increased and also contributed to the food supply during 1969.

Two species of voles were caught, Richardson's vole or water rat *(Microtus richardsoni)* and the Oregon creeping vole *(M. oregoni)*.

Richardson's voles inhabit chiefly alpine and subalpine areas (Ingles, 1965; Maser and Storm, 1970), but on the study plots their range had descended into the Transition zone. Water voles are semiaquatic and depend upon water for protection (Bailey, 1936). None was caught in the forest. In the second year after logging, however, they appeared along the stream in Plot 2. Water voles also were present on Plot 3, where they were more common and widely dispersed because of the greater amount of suitable riparian habitat.

Creeping mice occur throughout Oregon west of the Cascade Mountains, except for the riparian valley meadows of the Willamette Valley, where they are replaced by *M. canicaudus* and *M. townsendii.* Creeping mice are found in almost all well-drained forest-land habitats but avoid wet or marshy areas. They were the fourth most prevalent species caught (636 individuals) and comprised 17.4 percent of the total animals trapped. They were dispersed over the clearcuttings studied and not confined to a specific microhabitat as was the water vole. Their density remained low on the forested plot (Table 4), but increased abruptly on both clearcuttings.

Little is known about the feeding habits of *M oregoni,* except that it feeds upon green grasses and other vegetation (Bailey, 1936). Creeping voles live-trapped on the study areas readily ate Douglas-fir seeds, but showed only a slight preference for the tree seeds over rolled oats.

Discussion

Even though it was in an earlier seral stage, brush cover on the unburned Plot 2 was of greater density during the third year of comparisons, than cover on the slash-burned Plot 3. Density was largely due to the increased height and spread of vine maple, rhododendron, dogwood, and hazel. Development of brush species on the burned-over plot was retarded and reduced by destruction of above-ground parts of the plants during the fire.

Herbaceous cover increased on both clearcuttings, but at the end of the third year there was a significant difference between plots. Cumulative effects of increased com-

petition from brush, especially vine maple and other woody shrubs, gradually decreased the density of the herbaceous cover on the unburned plot.

Herbaceous plants are prolific seed producers during the pioneer stage on fresh clearcuttings. Individual seeds of many plants are small, but the seed volume is often large. Groundsel, for instance, an important pioneer plant on burned-over areas, has an average seed density of 770,000 seeds per acre (1,901,900 per ha) (West and Chilcote, 1968). One achene weighs an estimated 0.19 mg and the average weight of seeds produced per acre is 0.32 lb (359 gm per ha). This figure represents the potential seed production of only one plant species. Seeds of the willow-herbs were plentiful. The small coma-borne seeds matured and dispersed in early summer, and the large quantity of seed produced formed a dense snowy layer on the ground after dissemination. Seeds of *Cirsium* were noted frequently at feeding stations of chipmunks and graydiggers in late summer. Production of Douglas-fir seed, although variable from year to year, was more than 1.7 lb (2 kg per ha) per acre on Plot 1 during the fall and winter of 1968.

The effects of habitat alterations on small mammals are difficult to assess because the specific requirements of most species are largely unknown and cannot be emphasized in detail. Many species are restricted to a definite habitat type because of their adaptation to a particular mode of existence, and data concerning the unknown variables are missing. Also, some small mammals have the ability to adapt to adverse conditions for the short time necessary for the unbalanced habitat to recover.

Certain species, such as arboreal squirrels, rarely ventured into open areas far from timber. Marsh shrews and water voles were limited to riparian areas of grassy and herbaceous vegetation.

Shrews, primarily Trowbridge shrews, not found in large numbers in old-growth Douglas-fir (Gashwiler, 1970), were common on study plots where sufficient cover of decaying litter and shrubby vegetation existed. Differences in densities of shrews on the plots appeared to be related primarily to differences in ground cover. The uncut forest on Plot 1 was covered densely with a shrubby understory and a layer of matted, decomposing litter, which was inhabited by small arthropods such as mites, millipedes, pseudoscorpions, flies, and beetles. Plot 2, unburned, although covered with logging debris and new plant growth, had bare ground estimated at 40 percent the first year after logging. This situation created an unfavorable environment for small organisms. The fresh slashings on this clearcutting, however, attracted beetles of many species. Bark beetles (Scolytidae), long-horned wood borers (Cerambycidae), metallic wood borers (Buprestidae), and click beetles (Elateridae) were numerous. These beetles in turn attracted predators such as checkered beetles (Cleridae). Plot 3 had little logging debris on the area because the slashings had been burned. Wood boring beetles were scarce. Butterflies (Lepidoptera), their larvae, and bees and wasps were plentiful. Pollen-feeding insects (including beetles) were common on flowers of the thistles. Plot 3 also had more bare ground, which could have influenced the abundance of shrews by adversely affecting the food and cover available.

Sorex sp are reported to consume some vegetation including conifer seed (Moore, 1940; Kangur, 1954). *Soxex Trowbridgii* ate 38 percent of the Douglas-fir seed in the bait of the live traps and *S. vagrans* ate 15 percent. Neither species could be kept alive on Douglas-fir seed, however, and it is still uncertain as to what role conifer seeds play in the diet of the shrews.

The populations of chipmunks varied in density from year to year and among treatments. Townsend's chipmunks are diurnal, more arboreal in habits than mice, and prefer timber and shrubby brush areas while avoiding areas that are semi-bare. Chipmunk densities in the timber and on the advanced clearcutting were similar, but the density was low on Plot 2 the summer after logging. The chipmunks captured on Plot 2 were caught primarily around the perimeter and close to timber. The chipmunks may have avoided bare and semi-bare ground because of its higher daily soil-surface temperatures. Chipmunks became more numerous within the unburned unit Plot 2 after woody brush species increased in height and density.

Deer mice are adaptable and have been reported as numerous on partially open or disturbed sites such as those in early successional stages (Williams, 1955; Hooven, 1958). Deer mice were not abundant in the control areas, but increased in numbers on both clearcuttings after logging. The increase of *Peromyscus* was believed to be related to increased availability of seeds and insects as well as to reduced cover. Gashwiler (1965) reported that deer mice showed no response to current tree-seed abundance the first fall, but a marked response occurs the fall after a moderate or heavy seed crop. Deer mice in our study definitely increased in the fall with the occurrence of a heavy Douglas-fir seed crop.

Microtus oregoni was influenced strongly by vegetative cover. It was uncommon in closed stands of timber and its density in the forest remained low in comparison with that of the clearcuttings, where it was more numerous. In contrast to *M. pennsylvanicus,* which shows a positive response to vegetative increase (LaBue and Darnell, 1959) and negative response to vegetative decrease (Eadie, 1953), the creeping mouse becomes numerous on disturbed forest lands. Although it is found in greatest numbers on warm, dry clearcuttings, it requires a minimum amount of ground cover or mulch.

Snowshoe hares are not uncommon in the uncut forest, but peak populations appear to occur more prevalently in brushy clearcuttings or burns. Densities up to five hares per acre were noted in the Cascade Mountains on older burned-over areas (Black, 1965).

Pocket gophers also are restricted to early stages of plant succession in the western Cascade Mountains. Some indications of burrowing occurred on the study plots, with no sign of gopher damage to conifers. Clearcutting in subalpine areas, however, creates a more favorable condition for the gopher, and regeneration of nearby alpine clearcuttings often has been retarded seriously by their increase.

Previously, some small mammals were noted as having the ability to adapt to adverse conditions for short periods. Animals that store food are the most successful. *Peromyscus* not only gathers and stores food, but is omnivorous and can feed successfully on insects and green vegetation. These habits have enabled it to survive successfully through abrupt vegetational changes, including large, severe fires. Chipmunks also collect seeds, and germinating caches of up to 400 Douglas-fir seeds have been found. They also feed on insects, but they have not been observed to do so as intensively as *Peromyscus.* Pocket gophers use large amounts of vegetation. Their ability to survive fires is unknown, but gophers on areas where the vegetation has been removed chemically remain active for months before decreasing. Mountain beaver have the same ability, as they have been observed to be active on burned-over areas for at least eight weeks after a slash fire removed all vegetation.

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Variation in Foliar Macronutrients of One Year Old Sitka Spruce Seedlings of Ten Provenances[2]

Abstract

The genetic variation of foliar macronutrients of 10 Sitka spruce (*Picea sitchensis* (Bong.) Carr.) provenances was studied, but no geographical pattern of variation detected in Ca, Mg, P and N needle contents. Only K showed significant provenance to provenance variation.

Introduction

Differences in mineral nutrient concentrations among provenances of conifer species have been found recently (Mergen and Worrall, 1965; Steinbeck, 1966; Van Den Driessche, 1969, 1973). Although the significance of these differences is not unequivocally interpretable at present (Reuther and Smith in Childers, ed., 1954; Gouney, 1956; Lavender and Carmichael, 1966; Leaf, 1968; Voigt, 1968; Lavender, 1970; Waring and Youngberg, 1972); they possibly have some bearing on differences in growth behaviour among provenances.

In 1971, 545 single tree progenies of 38 provenances of the 1970 I.U.F.R.O. Sitka spruce (*Picea sitchensis* (Bong.) Carr.) collection were sown in a new British Columbia Forest Service nursery at Surrey as part of an extensive study of the genetic variability of Sitka spruce natural populations (Falkenhagen and Sziklaï, in press). Foliar analyses of ten selected provenances of Sitka spruce (Table 1) were performed in order to detect any genetically based variation in mineral content which could be related to their geographic origin.

Methods and Material

The material used comes from the 10 seedlings which were growing in polystyrene foam containers in 1971. The origins of the provenances are shown in Table 1.

Modern cultural techniques for growing seedlings were employed (Arnott, 1971). The ten selected provenances were sampled in February, 1972, still quiescent. The provenances were chosen according to their places of origin along a latitudinal gradient. After freeze drying, the needles were separated from the stem and milled, then they were digested in perchloric acid mixture. Potassium was determined by emission and calcium and magnesium by atomic absorption. Phosphorus was determined by the molybdenum blue method of Dickman and Bray. Nitrogen was determined by the well-known semimicro Kjeldahl method. The methods used are all outlined by Chapman and Pratt (1961).

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TABLE 1. Geographical coordinates and foliage analysis of the Sitka Spruce provenances studied. (+)

No. of the Prov.	Name	°Lat	°Long.	Elev. feet	% DRY NEEDLES N A	N B	N D	P A	P B	P D	K A	K B	K D	100 ppm DRY NEEDLES Ca A	Ca B	Ca D	Mg A	Mg B	Mg D
3	Big Qualicum River	49.38	124.62	0	1.24	1.16	1.26	.53	.44	.49	78	79	87	16	15	18	29	29	31
4	Salmon Bay	50.38	126.96	0	1.27	1.12	1.46	.45	.39	.51	71	70	74	14	17	17	31	29	27
15	Aberdeen Creek	54.20	129.82	0	1.26	1.34	1.38	.35	.46	.57	71	78	74	10	14	18	31	29	29
23	Mosspoint, Annette Island	55.03	131.55	0	1.08	1.24	1.22	.49	.42	.32	62	62	70	17	13	18	33	31	27
25	Old Hollis	55.47	132.67	0	1.24	1.34	1.35	.50	.35	.45	72	80	66	17	16	16	31	36	25
27	Ohmer Creek	56.58	132.73	25	1.44	1.21	1.40	.58	.53	.50	52	75	70	15	17	18	33	31	29
28	Duck Creek	58.37	134.58	100	1.40	1.36	1.35	.50	.39	.43	76	69	62	14	18	15	38	33	29
32	Tahsis 1	50.08	127.50	100	1.18	1.16	1.32	.50	.42	.55	71	78	81	14	16	15	31	28	27
37	Moresby Island Cumshewa Inlet	53.05	132.08	200	1.33	1.25	1.24	.43	.46	.49	72	76	66	15	17	18	29	29	31
40	Masset Inlet	53.92	132.08	0	1.14	1.32	1.22	.42	.47	.58	74	76	76	15	17	15	31	28	29

(+) In the nursery, three blocks out of four were sampled: the blocks A, B and D

Results and Conclusions

The results of the analyses are shown in Table 1. The analyses of variance show that there are no significant differences among the provenances for all the elements analyzed except for potassium. The anova model was the randomized complete block design with 3 blocks.

The Duncan's test for potassium is as follows ($= 0.05$):

Provenance number	3	32	40	15	25	4	37	27	28	23

Table 2 shows the mean K content in 100 ppm and the mean epicotyl length in mm.

TABLE 2. Mean K content and the mean epicotyl length.

Provenance number	K content (100 ppm)	Mean epicotyl Length (mm)
3	81	87
32	77	79
40	75	89
15	74	81
25	73	73
4	72	85
37	71	88
27	69	66
28	69	68
23	65	67

There is a tendency for low latitude sources to show higher K concentrations as a significant correlation coefficient of –0.70 between K needle content and latitude shows it. There is also a significant correlation between K content and epicotyl length ($r = + 0.68$). Therefore, one could hypothesize that the provenances with higher dry matter production also have the higher rate of K accumulation. However nutrient absorption, translocation, and loss in forest-trees are not well understood (Voigt, 1968) and a definite interpretation is not possible at the present time. The recent analyses of Sitka spruce seedlings by Benzian and Smith (1973) are not directly comparable as they are based on the analyses of whole plants.

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Comparative Food Habits of Oregon Nuthatches

Abstract

To compare habitat use in subdivisions in the Nuthatches of western Oregon, seasonal collections were made of White-breasted Nuthatches in Oregon white oak, and Red-breasted Nuthatches in Douglas-fir forests. Collections were also taken of White-breasted, Red-breasted, and Pygmy Nuthatches living sympatrically in Ponderosa pine forests. The food items in the gizzard and anterior alimentary canal were removed in the laboratory and identified in most cases as far as family. The results indicated that the White-breasted Nuthatch in the white oak was more of a generalist than the Red-breasted Nuthatch in the bordering Douglas-fir forests. In the Ponderosa pine, dietary overlap among the three nuthatch populations found was highest in the breeding and winter periods. During the post-breeding period, the White-breasted Nuthatch population took a large number of woodboring beetles, and the pygmy population concentrated heavily on leaf beetles, shifting similarities in the diets of the three species.

A great deal of dietary overlap occurred between the Red-breasted populations in the Douglas-fir and the Ponderosa pine during all seasons. Dietary overlap between the White-breasted populations in the Oregon white oak and the Ponderosa pine was not as pronounced. A significant difference between the food size of the White-breasted populations in the oak and pine was shown throughout the year, while the Red-breasted Nuthatches in the Douglas-fir and pine showed a significant difference in food size selection in the post-breeding and winter periods. The presence or absence of congeneric species was found to affect the food type and size of food selection.

Introduction

A number of habit studies exist which compare bird species that occupy similar habitats (*e.g.,* Snelling, 1968; Weeden, 1969; Baldwin, 1971a). Such studies, however, compare the type of food taken by similar species only in the spring and summer months. Only a few studies examine the interseasonal food habits among similar species in both allopatric and sympatric situations. This study examines the trophic relationships among three species of nuthatches in western Oregon. In the area bordering Willamette Valley and the Coast Range, the White-breasted Nuthatch *(Sitta carolinensis)* is commonly found in Oregon white oak *(Quercus garryana)* stands. The Red-breasted Nuthatch *(Sitta canadensis)* is more common in stands of Douglas-fir *(Pseudotsuga menziesii),* western hemlock *(Tsuga heterophylla)* and grand fir *(Abies grandis)* (Anderson, 1972). White-breasted and Red-breasted Nuthatches live sympatrically with Pygmy Nuthatches *(Sitta pygmaea)* in the Ponderosa pine *(Pinus ponderosa)* forests on the eastern slope of the Cascade Range 160 km to the east of the Willamette Valley.

In order to compare and assess the pattern of habitat use and subdivision by the nuthatches in the two areas of western Oregon, I analyzed digestive tract contents during the following periods of time: breeding (May, June, July 1969); post-breeding (August, September 1969); and winter (November 1969 through February 1970).

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Methods

Birds were collected by shotgun from three Oregon white oak stands and four Douglas-fir stands in the western part of the Willamette Valley near Corvallis, Benton County, Oregon, and from two Ponderosa pine stands 8 km west of Sisters, Deschutes County, Oregon, in the Oregon Cascades during the breeding, post-breeding, and winter periods. The sample size from each population during each period was 7 to 12 individuals. I excised digestive tracts of the birds in the field and placed them in vials of 4 percent formalin. Then I placed the bodies of the birds on ice and later froze them when I returned to the laboratory. The food in the gizzard and anterior alimentary canal was removed in the laboratory, and I identified the food items, in most cases as far as to family. The total number of each food type, the greatest length of each food item, and an estimate of the percent of the total volume it occupied in the stomach were recorded. The estimate of percent volume was made by placing the food items on a Petri dish over a piece of graph paper and making a visual estimate. Animal food items were preserved in isopropyl alcohol while plant materials were dried and saved.

Taxonomic diversity calculations were made on the total number of food items with the information theory index of diversity, $H = -\sum_{i=1}^{S} P_i \log_e P_i$, where P_i = the proportion of the total number of individuals belonging to the ith taxon and S = the number of species in the sample (Shannon and Weaver, 1949).

In order to examine the degree of overlap in the diets of nuthatch populations during the three seasons, I used Horn's (1966) index of overlap, Overlap $= R_o = \frac{H_{max} - H_{obs}}{H_{max} - H_{min}}$. H_{max} = the value obtained in the two populations had no taxonomic overlap in their diet, H_{min} = the value obtained if the populations had equal porportions of each taxon and H_{obs} = the sum of the H value from each population. Overlap (R_o) compared the taxonomic compositions and numbers of items in the diets of the different populations studies.

Results

Species comparison—Willamette Valley. Animal and plant contributions of more than 8 percent of the total stomach volume are shown in Figure 1 for the nuthatch populations of western Oregon.

In the oaks, the White-breasted Nuthatches' diets consisted of a large percent of weevils throughout the year. In the breeding and post-breeding seasons, earwigs (Dermaptera) made up a large proportion of their diets. While Stallcup (1968) observed the White-breasted Nuthatches foraged on the trunks and branches more than 50 percent of their time, I found the bark beetles, which were found in large numbers in these areas, did not constitute a significant proportion of their diets. Since the bark beetles were small and were found under the bark, the large bill of the nuthatch may not have been suited to extracting these beetles. Diversity of White-breasted Nuthatch diet in the oaks decreased during winter (Table 1). Since this area was without foilage during this period, the birds foraged over the branches and trunks and moved to shrubs for short periods, often finding concentrations of insects which provided large parts of

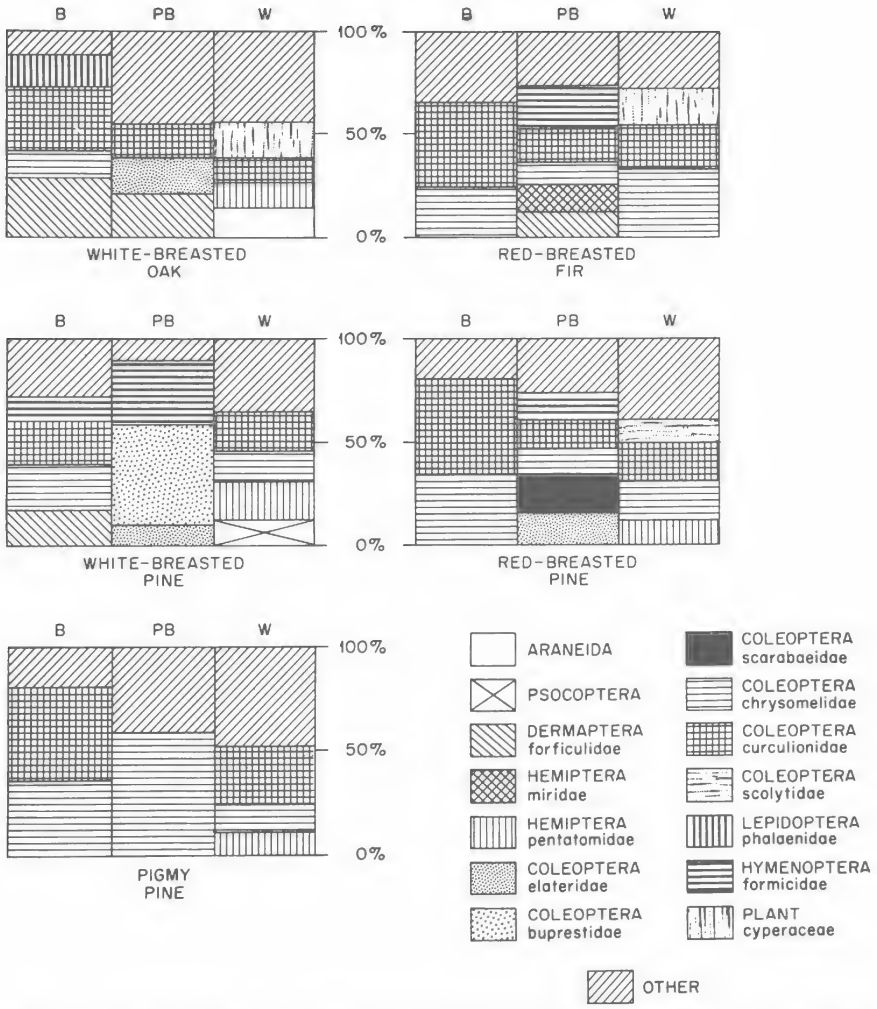

Figure 1. Upper digestive tract contents of nuthatches by percent volume (number in parentheses is the number of birds examined). B = Breeding season, PB = post breeding W = Winter, OAK = Oregon white oak, FIR = Douglas-fir, PINE = Ponderosa pine.

their diets. The large category "Other" in Figure 1 for wintering White-breasted Nuthatches in the oak represented a rather even distribution among 14 taxa. I only found 10 taxa in the stomachs of breeding White-breasted Nuthatches.

During the breeding period (Figure 1) White-breasted Nuthatches in the Willamette Valley took a greater variety of food items than the Red-breasted Nuthatch population. The latter concentrated on weevils (Coleoptera and Curculionidae). During the post-breeding period their diet included five major food items while the White-breasted Nuthatch population diet took a large number of many different insect species.

In winter, plants were a part of both nuthatch populations' diets, with sedge (Cy-

TABLE 1. Diet Diversity of Nuthatches.

	Breeding H	Post-breeding H	Winter H
OREGON WHITE OAK			
White-breasted Nuthatch	1.88	2.18	1.31
DOUGLAS-FIR			
Red-breasted Nuthatch	2.09	2.00	2.21
PONDEROSA PINE			
White-breasted Nuthatch	2.11	1.32	2.21
Red-breasted Nuthatch	1.36	1.84	1.98
Pygmy Nuthatch	1.13	1.74	2.11

peraceae) seeds composing 17 percent of each diet. Plant material was found in negligible amounts in their diets during the rest of the year.

Bark beetles (Scolytidae) increased from 3 percent in the post-breeding period to 7 percent in winter for the Red-breasted population. Stink-bugs (Pentatomidae) and lady-bugs (Coccinellidae) were found in their diets only in winter. This shift probably indicated a tendency to forage more on the large proximal branches and trunk during the winter period.

Seasonal dietary overlap is shown in Figure 2. The greatest dietary similarity in the White-breasted Nuthatch in the Willamette Valley is seen between the breeding and winter and the post-breeding and winter. Here the lack of foliage in part accounts for the divergence. The Red-breasted Nuthatch of the Douglas-fir shows the greatest overlap between the breeding and winter periods with the lower overlap in the post-breeding and winter comparison.

A comparison of the food size selected seasonally by the different nuthatch populations is made in Figure 3. A one-way analysis of variance indicates a difference in the food size taken by the White-breasted and Red-breasted populations occurs only in the winter period.

Species comparison—Ponderosa Pine. During the breeding period, diets of the Red-breasted and Pygmy populations were dominated by weevils. Ants (Formicidae) were found in varying amounts in the stomachs of all nuthatches during the breeding and post-breeding period, whereas few were found in winter.

During the post-breeding period, shifts occurred in the diets of the different populations. In Pygmy Nuthatches' diets leaf beetles increased from 37 to 59 percent and weevils decreased from 45 to 7 percent of the total volume. White-breasted Nuthatches had a large proportion (48 percent) of wood-boring beetles (Buprestidae) in their stomachs. Click beetles (Elateridae) appeared in the diets of both Red-breasted and White-breasted Nuthatch populations, and scarab beetles (Scarabaeidae) were found in the Red-breasted Nuthatches.

A large variety of food items was common in winter, thus "other" categories in Figure 1, consisting of taxa individually contributing less than 8 percent of the diet, were rather large. Plants played a small role in the nuthatches' diets during this period. Six percent of the Red-breasted's diet was sedge while grass (Gramineae) seeds contributed 2 percent in the diet of White-breasted Nuthatches. Several unidentified seed types made up 6 percent of the volume of the White-breasted's and Red-breasted's diets and 4 percent of the Pygmy Nuthatch's diets.

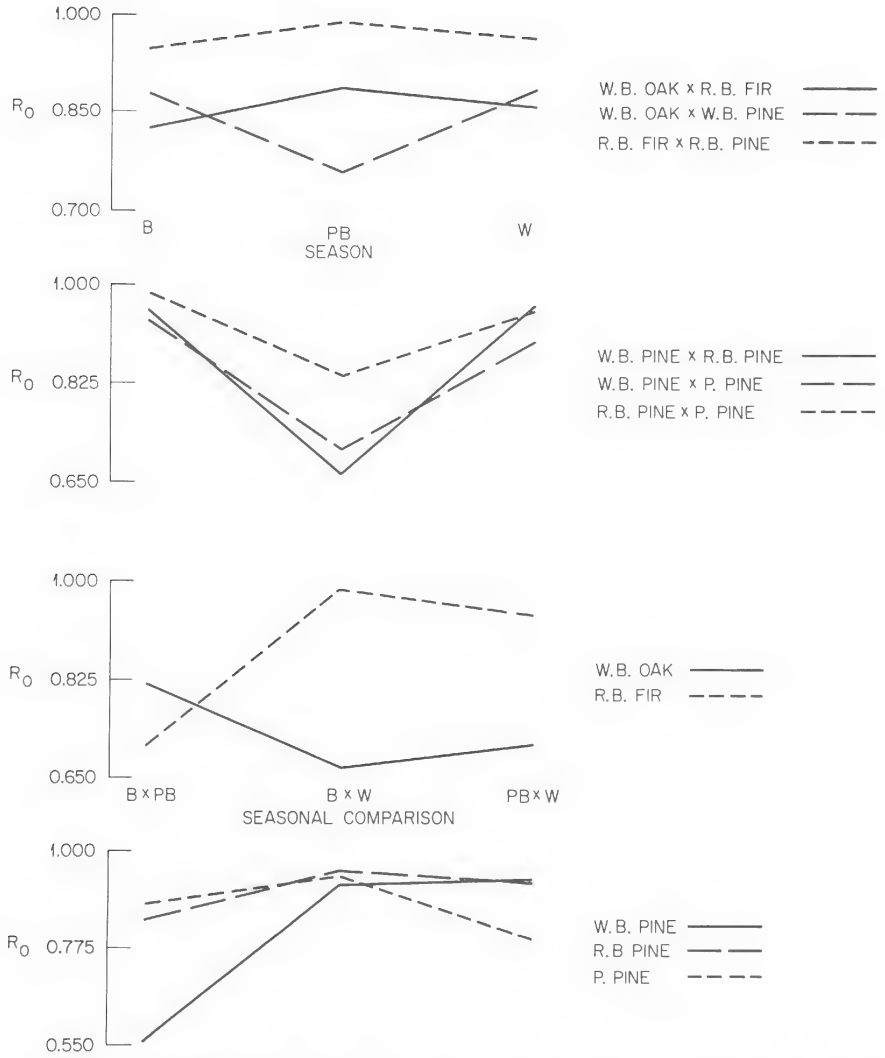

Figure 2. Indices of overlap (R_o) within and between nuthatch populations. See text for formula. WB = White-breasted Nuthatch, RB = Red-breasted Nuthatch, P = Pygmy Nuthatch, B = Breeding period, PB = Post-breeding period, W = Winter period, OAK = Oregon white oak, FIR = Douglas-fir and PINE = Ponderosa pine.

I noted a shift in the type of food taken during winter. Many more bark-dwelling insects were found in stomachs during this period than in the breeding and post-breeding periods. This was particularly noticeable in Red-breasted and Pygmy Nuthatch diets. Bark beetles increased from 6 to 12 percent in the Red-breasted's diet and 3 to 7 percent in the pygmy's diet between the post-breeding and winter period.

The diversity (Table 1) of the White-breasted Nuthatch diet dropped during the post-breeding period when only three taxa made up the bulk of the food selected. The

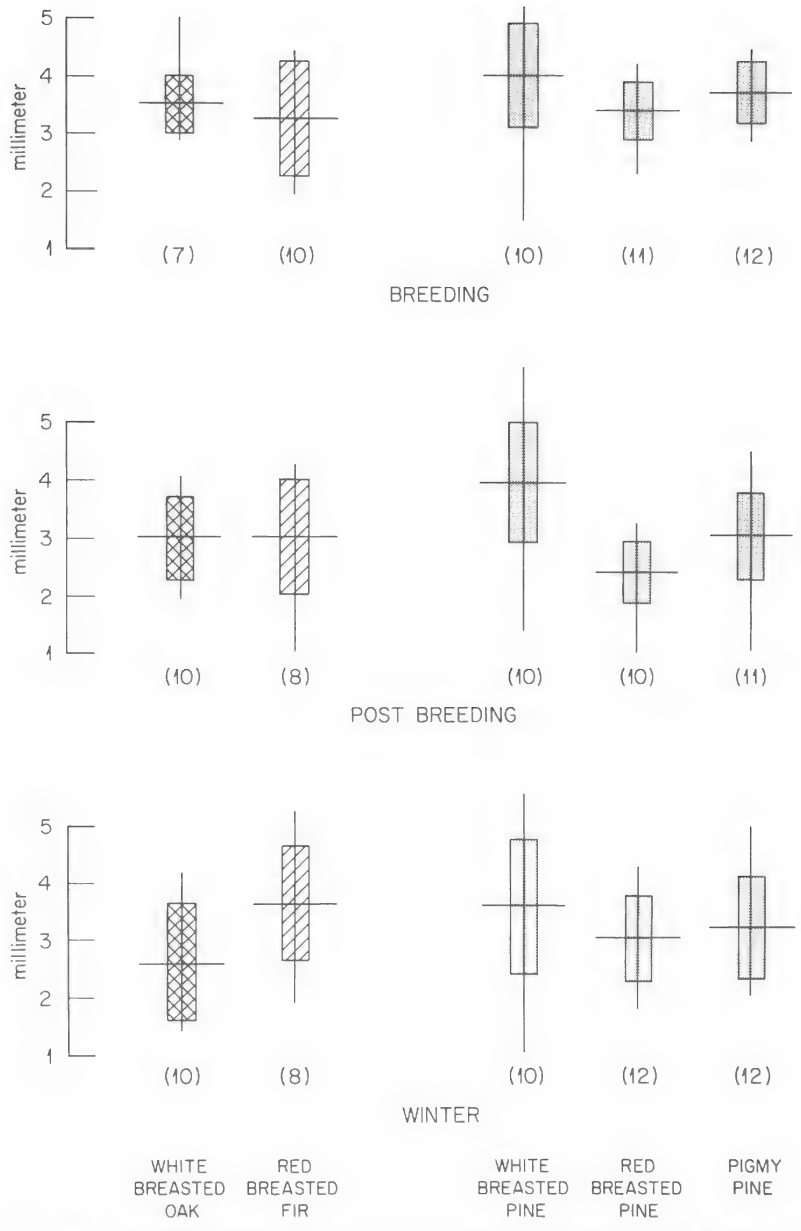

Figure 3. Mean length of each food item in stomachs of nuthatches during each season. Vertical line = range, horizontal line = mean, number in parentheses is the number of birds examined. Symbols as in Figure 2.

dietary diversity of the Red-breasted Nuthatch became higher in the post-breeding and again in the winter periods. The Pygmy Nuthatch ate a greater percentage of leaf beetles and weevils during the breeding period; during the post-breeding season, leaf beetles made up a large percentage of its diet.

The White-breasted population in the pine had the lowest overlap value between the breeding and the post-breeding periods. This fact could reflect the increase in the variety of food available in the breeding season and the selection of some food from the available items by the birds. Seasonal comparison between the Red-breasted and Pygmy populations in the pine did not show great variations.

Dietary overlap among the three nuthatch populations was very high in the breeding and winter periods (Figure 2). During the post-breeding period, the White-breasted population took a large number of wood-boring beetles while the Pygmy population concentrated heavily on leaf beetles (Figure 1) thus shifting similarities in the diets of the three species.

The one-way analysis of variance indicates a significant difference in the size of the food selected by at least one of the populations during each period (Figure 3).

Species comparisons between Cascades and valley. A great deal of dietary overlap occurred between the Red-breasted populations in the two areas during all three seasons (Figure 2). Both populations took very similar food and in similar relative amounts. Dietary overlap between the two White-breasted populations was not as pronounced. As the diet of the Red-breasted populations did not shift greatly during the year, it appeared that the addition of congeneric populations in the habitat had its greatest affect on the White-breasted populations. This species appeared more opportunistic in its food selection than the Red-breasted (Table 1) and thus could shift to other foods more rapidly.

A significant difference between the food size of the White-breasted population in the pine and oak occurs in all periods (Figure 3); however, the Red-breasted population in the pine and Douglas-fir has significant difference in food size only in the post-breeding and winter periods. White-breasted Nuthatches in oaks take smaller food items during each period than the White-breasted in the pine. Food size of the Red-breasted population in fir is larger in the post-breeding and winter periods than is the Red-breasted in pine.

Discussion

The habitat relationships shown by the nuthatch species are similar to those of other congeneric species occupying a similar habitat. Hartley (1953) documents such relationships of titmice in English woodlands and shows that species are separated by their feeding habitats and foraging area. Furthermore, it is known that sympatric congeneric nuthatches may vary morphologically from their allopatric populations (Vaurie, 1951; Brown and Wilson, 1956). While speciation undoubtedly plays a role in habitat selection, local habitat structure also influences morphology and dietary composition. Pines with their plated bark are probed by the White-breasted Nuthatches. Oaks have smooth bark with longitudinal furrows requiring a different method of food procurement.

Habitat structure as well as climate may affect insect population. The Willamette

Valley with its mild winters is likely to support a different insect population than the Ponderosa pine forests at higher elevations.

A study by Tinbergen (1960) of several species of tits showed that there was a marked difference in percentage composition between the insect fauna of an area and the food selected by birds. The more abundant insects were not always the common food item. Baldwin (1971b) calculated an *index of utilization* for the Lark Bunting *(Calamospiza melanocorys)* by collecting $0.1m^2$ sod samples in areas where the birds were observed feeding. By examining the insects and comparing the results of a stomach analysis of the birds he was able to show that the birds exercised a selective behavior for some species of insects and plants and took very few of other species present.

Some predators are more selective than others. Red-breasted Nuthatches in Ponderosa pine appear to be more selective predators than White-breasted Nuthatches, as Red-breasted select fewer prey. Many factors, such as foraging tactics, social behavior, morphological variation, and previous experience of the bird influence the type of prey chosen (see Wiens, 1971). Some territories may have particular prey items. In other cases, the time spent foraging and the influence of other birds in a flock in the same neighboring habitat alters foraging patterns. The prey species may influence the dietary composition of a predator. Some prey items are available only during certain daily or seasonal time periods. Some stages of the life cycle of insects may be more palatable to the predator. Climatic changes affect the abundance of prey species. Seasonal shifts in the food of the nuthatch species indicate selective patterns. In three of the five populations the "Other" category is smallest in the breeding season. Populations find their preferred food and concentrate on it during this period. The White-breasted Nuthatch population in pine has a large proportion of Buprestids during the post-breeding season, which could reflect an outbreak of the beetles during this period. Both Red-breasted and Pygmy Nuthatch populations select food from only a few taxa during the breeding season though many forms are available (Figure 1).

The White-breasted Nuthatch appears to be more of a generalist than the other two species. This finding is correlated with the results of Stallcup (1968) who compares the foraging behavior of the three nuthatch species in Colorado and finds a shift in the White-breasted Nuthatches' foraging zones during the non-reproductive season when the Red-breasted Nuthatch forage in the area. The White-breasted populations can be viewed as valley and mountain ecotypes with the White-breasted populations showing a greater degree of food size variation and a smaller overlap of food than the Red-breasted populations.

Summary

To compare habitat use and subdivision in the nuthatches of western Oregon, seasonal collections were made of White-breasted Nuthatches in Oregon white oak and Red-breasted Nuthatches in Douglas-fir forests. Further samples were taken of White-breasted, Red-breasted, and Pygmy Nuthatches living sympatrically in Ponderosa pine forests. Diet overlap between the White-breasted population in the oak and the Red-breasted population in the Douglas-fir did not change appreciably during the year. Overlap in food selected by the three nuthatch populations in the pine was high during the breeding and winter periods. Significant difference between the food size of the

White-breasted populations in the oak and pine was shown throughout the year, while the Red-breasted Nuthatches in the Douglas-fir and pine showed a significant difference in food size selection in the post-breeding and winter periods. The presence or absence of congeneric species was found to affect the food type and size of food selected.

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Survival and Reproduction of Wild Game-Farm Pheasants in Western Oregon[2]

Abstract

Of the 1300 male game-farm pheasants *(Phasianus colchicus)* released in fall 1972 and 1973, none survived until the following spring; 60 percent were bagged by hunters. Female game-farm pheasants released in spring disappeared rapidly. Over a two year period only 17 young were produced by 335 female game-farm pheasants released in early spring. The population of wild pheasants declined about 60 percent from summer 1973 to summer 1974. Rate of recruitment of young, however, remained constant between years (4.9 young:female in late summer and 3.4 young:female in fall), and reproduction appeared to be normal. About 53 percent of the males on the hunting area were bagged by hunters. The long-term decline of pheasants in the Willamette Valley apparently is not a result of inadequate reproduction or excessive hunting mortality.

Introduction

Ring-necked pheasants were first successfully introduced into North America in the Willamette Valley, Oregon, nearly 100 years ago (Lauckhart and McKean, 1956). Although the pheasant initially adapted well to agricultural lands and rapidly became a popular gamebird, their population numbers have recently declined. In the Willamette Valley the population decreased from peak densities, measured in the fall of the year, of about 75 birds per 100 ha in the early 1960's to less than 25 birds per 100 ha in the early 1970's (Oregon Wildlife Commission, 1960-1974). Causes of the decrease are unknown.

The Oregon Wildlife Commission annually releases pheasants raised on game-farms (game-farm pheasants) to provide additional game for hunters and to augment the wild population. Male pheasants are released in fall prior to and during the hunting season; females, along with some males, are released in spring. Spring release of females facilitates operation of the game-farm (disposal of excess breeders), and also adds breeding age birds to the wild population.

In Oregon and other areas in the United States, hunters harvest from 50-70 percent of males released prior to and during the hunting season (Oregon State Game Commission, 1951; Hart *et al.,* 1956; Burger, 1964; Potter *et al.,* 1973); as high as 8 percent of males released in fall have been reported to be alive the following spring. Reproduction of females released in spring has varied from nil (Oregon State Game Commission, 1951), to each female released contributing one (Kabat *et al.,* 1955; Besadny

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[2] Study conducted under the auspices of Oregon Cooperative Wildlife Research Unit: U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, Oregon State University, and the Wildlife Management Institute cooperating. Oregon Agricultural Experiment Station Technical Paper No. 4142.

and Wagner, 1963), or two (Salter, 1949; Hansen, 1953), young to the fall population.

The purpose of this study was to estimate survival and reproduction of game-farm pheasants and to estimate reproductive performance of a wild population.

Study Area

The study was conducted at William L. Finley National Wildlife Refuge, 20 km south of Corvallis, Oregon. The area is characterized by a mild climate, with an average annual temperature of 12° C and average annual precipitation of 95.7 cm (U.S. Department of Commerce, 1973). Most precipitation occurs as rain during winter; summers are dry and warm.

The study area (1407 ha) encompassed nearly all of the suitable pheasant habitat on Finley Refuge and a small area adjoining the northeast side of the refuge (Fig. 1). Cover types utilized by pheasants on the study area consisted of light to moderately grazed or mowed grasslands (20 percent); unharvested native prairie of rank

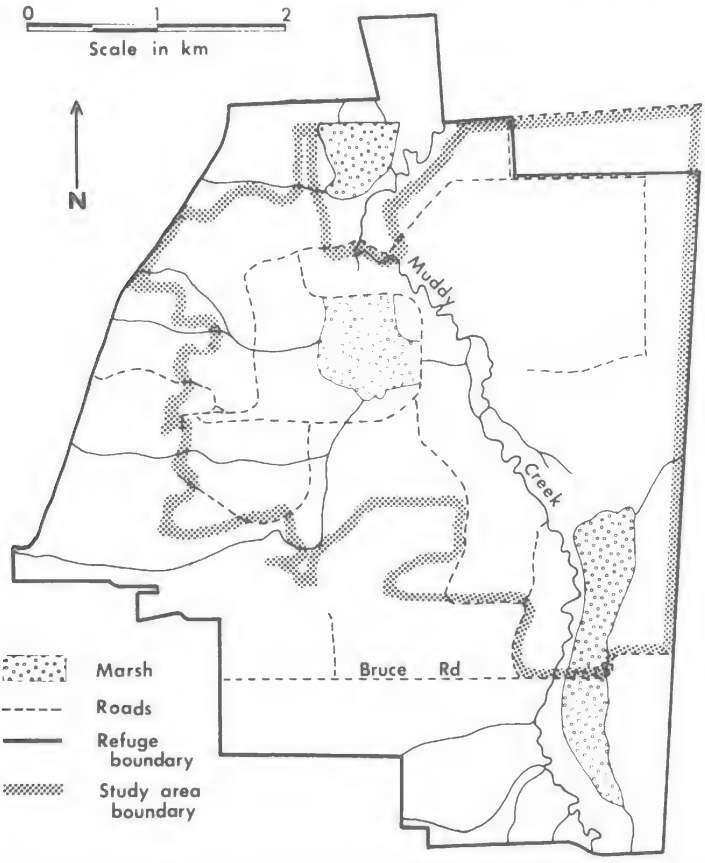

Figure 1. Study area and William L. Finley National Wildlife Refuge. Hunting area includes the portion of the refuge east of Muddy Creek and south of Bruce Road.

grasses, grass-like plants and short shrubs (30 percent); grass seed production fields (20 percent); marshes, which were mostly or completely dry in summer (15 percent); cereal grain fields (7.5 percent); and riparian Oregon ash (*Fraxinus latifolia* Benth.)-Oregon oak (*Quercus garryana* Dougl.) forests (7.5 percent).

Methods

Game-farm pheasants raised at E. E. Wilson Game Farm by the Oregon Wildlife Commission were released twice each year. In fall, 200 males were released the day before hunting season and four (1972) or five (1973) releases of 100 males each were made at irregular intervals during the remainder of the season. The hunting season extended from mid-October to the first week of November. Pheasants were also released in spring: 148 females and 57 males on 2 April 1973 and 187 females on 11 April 1974. Females and males released in spring were approximately one year old and had not been used in the breeding program at the game-farm; males released in fall were approximately six months old. Pheasants were released in small groups either throughout the hunting area (fall) or throughout the study area (spring).

Game-farm pheasants were tagged with solid-colored patagial streamers on the left wing (Anderson, 1963). Colors were dark blue, light blue, green, white, orange, black, and magenta.

Harvest information was collected at two self-service check stations on the hunting area at Finley Refuge. Information requested on self-checking forms included number of pheasants bagged, date, and length of hunt; return of patagial tags was also requested. In addition, during weekends and at other times of expected high activity of hunters, we examined all pheasants bagged by hunters for presence (game-farm pheasants) or absence (wild pheasants) of tags; age of wild pheasants was determined by probing the bursa (Linduska, 1943; Stokes, 1954; Robertson, 1958).

Harvest of wild males was determined by regressing the ratio of wild males harvested per hunter-hour of effort against days of the season, using data from the days when we examined the bag of hunters for the presence of wild males. Daily harvest of wild males for days when we did not examine bagged pheasants was calculated by multiplying the predicted bag of wild males per hunter-hour of effort times the number of hours of effort reported by hunters on the self-checking forms. The sum of these calculations added to the observed harvest of wild males yielded an estimate of total harvest of wild pheasants.

Systematic roadside counts were conducted in spring and fall; periodic counts were made during winter. Roadside counts consisted of slowly driving an established route and stopping periodically for one to five minutes at selected vantage points. Routes remained constant within a season but varied slightly between seasons because of variable road conditions. Most counts were conducted from ½ hour after sunrise until 2½ hours after sunrise; counts were occasionally conducted in the evening.

Censuses of broods were conducted during summer by searching the study area with trained dogs. Large open fields (harvested hay and grass seed fields), marshes, and forested areas were searched only on the periphery. The entire study was searched twice each summer (1973 and 1974). On occasion broods consisting of young pheasants only were observed but we assumed an unobserved female was present. Spatial distribution and age of young were utilized in estimating the number of broods present each

summer. Broods observed more than 0.8 km apart were considered as separate broods; 0.8 km is the approximate maximum diameter of the home range of pheasant broods (Kuck *et al.,* 1970; Hanson and Progulske, 1973). Broods containing young with an age difference of 10 or more days were also considered as separate broods. Age of young was estimated with the aid of a photographic guide (Minnesota Division of Game and Fish, 1965).

Data collection was initiated in October 1972 and terminated in September 1974. Thus, we have data for two fall periods (1972 and 1973) and for two summer periods (1973 and 1974).

Results and Discussion

Harvest and Survival of Game-Farm Males

Approximately 60 to 65 percent of game-farm males released in fall were bagged by hunters, *i.e.,* shot and retrieved (Table 1). The numbers of game-farm males harvested was derived by subtracting the estimated harvest of wild males from the total harvest reported by hunters. The harvest of game-farm males represents a minimum mortality estimate since crippled birds and birds lost to other causes are not included. Few game-farm males survived the hunting season and apparently none survived until the following spring (Table 2). Hence male game-farm pheasants released in fall made no reproductive contribution to the wild population at Finley Refuge. The 57 males released in spring 1973 were not marked and we have no information on their survival or reproductive activities.

TABLE 1. Harvest of male game-farm and wild pheasants on Finley National Wildlife Refuge, 1972-1973.

	1972	1973
Number game-farm males stocked	600	700
Number game-farm males harvested	380	454
Estimated wild males harvested	47	39
Total reported harvest	427	493
Percent of released game-farm males harvested	63.3	64.9
Percent of harvest composed of game-farm males	89.0	92.1

TABLE 2. Observations of wild male and game-farm male pheasants following hunting season of release, Finley National Wildlife Refuge.

	1972-1973		1973-1974	
Period of Observation	Number game-farm males	Number wild males	Number game-farm males	Number wild males
November-December	4	7	4	24
January-March	2	161	1	27
April-July	0	360	0	125

Survival and Reproduction of Game-Farm Females

Released game-farm females apparently survived only slightly better than game-farm males. In 1973, only 22 observations of game-farm females were recorded over a 50-day period following release of 148 females on 2 April. One game-farm female with a brood of four young was observed in summer adjacent to the study area.

Game-farm females were more readily observed following their release on 11 April 1974 (144 observations within 30 days after release). However, nearly all females had disappeared within 40 days after being released. In 1974, three game-farm females with 13 young, and one without young, were observed during the summer brood census.

Wild Pheasants: Sex Ratios of Adults

In August during the summer brood census 66 adult males and 58 adult females were observed in 1973, and 17 adult males and 20 adult females were observed in 1974. The age distribution of young pheasants indicated few females were incubating in August, and since trained dogs were used to locate pheasants in a systematic and complete search, we believe the sex ratio observed was relatively accurate. A small amount of bias may have occurred because of differential flushing patterns between the sexes. However, we have no reason to suspect that the sex ratio of adults is different than 1:1, and we have used this ratio in later calculations.

The sex ratio we observed is lower (fewer females/male) than that frequently observed in pheasant populations, although sex ratios of adults sometimes approaches 1:1 in unhunted populations (Dale, 1952). We have no explanation for the low sex ratio observed in our study.

Population Estimates

In 1974, 23 different broods (20 wild and 3 of game-farm origin) were estimated to be present on the basis of a difference in age, spatial distribution, or presence (game-farm pheasants) or absence (wild pheasants) of a patagial tag on adult females. In 1973, twice as many young were observed as in 1974 (Table 3) and differentiation of broods in 1973 proved difficult using the above criteria. Since the ratio of young to

TABLE 3. Observations of young and adult female wild pheasants during two censuses in summer and estimated number of broods present, 1973 and 1974. See text for criteria and methods of estimating number of broods.

	1973	1974
Number of females observed	29	14
Number of young observed	142	68
Young per female	4.9	4.9
Estimated number of broods	41	20
Ratio broods/young observed	0.29:1[1]	0.29:1

[1] From 1974 census.

adult female (4.9:1) and search effort remained constant between years, we assumed that the ratio between the number of broods present and the number of young observed should also have remained constant. Multiplying the ratio of broods per observed young (0.29:1) in 1974, when both were known, times the number of young observed in 1973 (142) yielded an estimated 41 broods present in 1973 (Table 3).

The number of unsuccessful females present was estimated by forming a ratio of females observed without broods to females observed with broods, and multiplying this ratio times the calculated number of broods present. Thus, we estimated there were 54 adult wild females (41 with broods and 13 without broods) in 1973 and 23 adult wild females (20 with broods and three without broods) in 1974. This estimate may

be biased because some lone females observed in early or mid summer may have produced young at a later date. However, our calculations indicate a high rate of success, while the bias, if present, should have caused an underestimate of success. Based on a 1:1 sex ratio, we estimated the total wild adult population at 108 and 46 in summer of 1973 and 1974, respectively.

The indirect estimate of number of broods in 1973 makes the estimate of population size in 1973 suspect. However, since search effort during the summer census was constant between years, the ratio of observed birds to estimated population size should be the same. These ratios for adult males and females were similar in 1973 and 1974 (Table 4) and hence the population estimates should at least be comparable between years.

TABLE 4. Relation of observations of adult male and female pheasants during two brood censuses to estimated number of each present, 1973 and 1974.

	1973	1974
Number males observed	84	31
Estimated male population	54	23
Ratio observations: population	1.56	1.35
Number females observed	29	14
Estimated female population	54	23
Ratio observations: population	0.54	0.61

Recruitment

Two estimates of recruitment were made; one when young were six weeks of age and one in October at the beginning of the hunting season. In both 1973 and 1974 the ratio of young to adult females observed during the brood census was 4.9:1 (Table 3). This ratio multiplied by the estimated number of adult females present each year indicated that 265 young were raised to six weeks of age in 1973 and 113 in 1974 (Table 5).

The second estimate of recruitment utilized the age ratio of males harvested and assumed that juvenile males were as likely to be harvested as adult males and the sex

TABLE 5. Estimated population size of wild pheasants at end of summer, 1973 and 1974.

	1973 Estimated Number	1974 Estimated Number
Adult Females	54	23
Females with broods	41	20
Females without broods	13	3
Young	265	113
Adult Males	54	23
Total Adults	108	46
Total Population	373	159

ratio of both young and adults was 1:1. Juvenile males are frequently more readily harvested than adult males (Kimball, 1948; Wagner *et al.,* 1965) but on heavily hunted areas vulnerability of adults and juveniles is nearly equal (Stokes, 1954; Hart, 1954). Finley Refuge is heavily hunted and we do not think the age ratio of harvested males is seriously biased.

The age ratio of harvested males in 1973 (1.7 young:1 adult) extrapolates to 3.4 young per adult female, assuming an equal sex ratio. This estimate is 30 percent lower than the 4.9 young per adult female observed during the summer brood census. The difference probably results from mortality of young from summer to late October and from imprecision of our estimates.

The age ratio of females in fall and winter is frequently used as an index of productivity. We have used the male age ratio from the harvest as an estimate of female age ratio during the fall. These estimates, 2.1:1 in 1972 and 1.7:1 in 1973, fall within the range of reported female age ratios (Table 6). Thus, while productivity is lower than at some areas, we judge that the population at Finley Refuge is reproducing satisfactorily.

TABLE 6. A comparison of age ratios of female pheasants from various areas.

Area and years studied	Fall and/or winter female age ratio (young per adult)	Reference
Pelee Is., Ont. 1946-50	2.2	Stokes 1954
California 1952-58	1.8	Harper 1960
Illinois 1947-48	2.5	Robertson 1958
South Dakota 1945-46	1.2	Kimball 1948
Utah 1953-54 and 1960-65	3.3	Stokes 1968
Wisconsin 1958-65	3.0	Gates 1971
Oregon 1972-73	1.9[1]	This study

[1] Calculated from male age ratios.

Hunting Mortality of Males

The estimated wild males harvested by hunters, 47 in 1972 and 39 in 1973, was about 10 percent of the total harvest of males (Table 1). The percentage of the male population harvested could only be determined in 1973. Only part of the study area was open to hunting and the second brood census in August indicated about 50 percent of the pheasant population present on the hunting area. Thus about 53 percent (39 of 73) of the wild males present on the hunting area in October were harvested. This rate of harvest of male pheasants is considerably lower than harvest rates reported from other areas (range 73-81 percent: Harper *et al.,* 1951; Stokes, 1954; Wagner *et al.,* 1965).

Conclusions

Game-farm pheasants apparently made little contribution to the wild population. To our knowledge, none of the males survived to reproduce and only 17 young were known to have been hatched by the 335 females released (0.05 young/female).

The disappearance of game-farm males could be attributed to mortality since 60 percent were known to have been harvested. We believe that the disappearance of females was also caused by mortality. Dispersal was probably limited because released game-farm pheasants tend to travel short distances when released (MacNamara and Kozicky, 1949; Harper *et al.,* 1951; Kabat *et al.,* 1955; Robertson, 1958; Burger, 1964), and the area surrounding the study area was poor quality pheasant habitat (coniferous forest to west and large grass seed fields to east). Only four game-farm pheasants were observed outside the study area.

The adult segment of the wild pheasant population declined 58 percent from summer 1973 (108) to summer 1974 (46); reduction of total population (adults and young) was 69 percent over the same period. Some of this decline may be attributed to extensive flooding of the study area during the winter of 1973-74. Reconstruction of the fall population level in 1972 (Table 7) indicated a decline of 17 percent from 1972 to 1973.

TABLE 7. Reconstruction of population in fall 1972 from harvest and age ratio of males and assuming the same mortality rate, sex ratio and distribution of pheasants in 1972 as occurred in 1973.

	1972		1973
Recorded harvest	47		39
Percent of population on hunting area harvested	(53)[1]		53
Percent of males on hunting area	(50)[1]		50
Number males on study area	178		146
Number females (1:1 sex ratio)	178		146
Total number pheasants	354		292
Percent change		–17.5	

[1] From estimates obtained in 1973.

The causes of the low density of pheasants (26.5 birds/100 ha in 1973 and 11.3 birds/100 ha in 1974) and apparent continued population decline are not readily discernible to us. Apparently neither reproductive failure nor excessive hunting mortality were responsible. Others have also noted adequate reproduction in declining pheasant populations (Gates, 1971; Anderson, 1964; Ellis and Anderson, 1963). We suggest that both the low population density and the population decline are associated with an undefined interaction of habitat quality and mortality.

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Computerization of Data Handling for Long-Term Forest Research Plots

Abstract

Tree and stand development data from long-term research sample plots in northern Idaho have never been utilized as fully and effectively as they might have been because of time required to select, check, and arrange all appropriate portions for analysis. This report describes development of automated data processing procedures that make access to desired data easy and inexpensive and also provide editing capabilities, improved insurance against data loss, and printed field forms keyed to each plot for recording the next remeasurement.

Use of permanent sample plots in forest research in the United States dates back at least to 1912, when a formal plan for their establishment and measurement and for recordkeeping by the U.S. Forest Service was published. Typically, plots of this kind are marked and referenced as areas each a tenth-acre or larger in size. Measurements of diameter and height and some specific notations of condition have been taken on individually numbered and tagged trees on sample plots at intervals of 5 or 10 years. When maintained over long periods, such records provide information on the variability and trends of tree growth, mortality, and coincident stand conditions that cannot be obtained in any other way.

The Northern Rocky Mountain Forest Experiment Station first installed permanent sample plots in 1914 at the Priest River Experimental Forest. Over the next 40 years, more than 250 plots were established in northern Idaho stands. Although many of these plots had limited application because of special study objectives or early loss from disturbance, 109 have provided up to 60 years of tree and stand development data. About half of these plots are still being maintained and are remeasured at 5- to 10-year intervals. Nearly 350,000 measurements have been made to date on about 60,000 individual trees, describing not only their growth and mortality, but changes in the structure, density, and species composition of sampled stands.

Various parts of these data have been used repeatedly for such purposes as comparing the growth of different species and predicting the development of similar stands. However, the information has never been utilized as fully and effectively as it might have been because of the time required to select, check, and arrange all suitable portions for analysis.

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This report describes the development of automated data processing procedures that make access to desired data easier and less costly than heretofore and provide editing capabilities, safer storage, and printed field forms keyed to each plot for subsequent remeasurements. Procedures used elsewhere can be applied most directly to similar sets of timber growth and yield data, but their possible application to other kinds of research has been demonstrated by successful adaptations to long-term hydrologic records.

Data Handling Procedures

Data from the northern Idaho plots recorded for each tree included plot number, tree number, species, diameter at breast height, crown class, and certain other important characteristics of tree condition. In 1931, machine tabulation techniques became available; so the nonnumeric variables were coded and most previous and subsequent data were put on punchcards. In recent years the records for active plots have been kept current by a data-handling system that merges data from old cards with data from new cards, creating a completely updated card deck. However, problems and limitations of the system became obvious soon after its inception. In some cases, data from recent remeasurements that had been added to field sheets were overlooked and, in other cases, data that had been put on cards were stored and never merged into current decks. In all instances, the latest card decks had a high frequency of errors of several kinds that were difficult and time consuming to detect and correct. These errors occurred during field recording, keypunching, and programming or, occasionally, when communication between computer programmers and research foresters was inadequate. Moreover, old decks, new decks, and merged decks began filling and overflowing limited storage space until no one knew precisely the location and status of cards for specific plots.

Early in 1972, the programmers and research foresters involved began to discuss the need for using modern computer capabilities to handle data from permanent sample plots more efficiently. Subsequent meetings and experimentation produced a set of operational procedures and programs called the Permanent Sample Plot System (PSP).[2] This system was designed to meet the following objectives: (1) inexpensive operation, (2) good insurance against loss of data, (3) thorough documentation, (4) small space needs for data storage, (5) good capacity for program or data additions, (6) routine spotting of common errors in data entries, and (7) easy retrieval of data.

Initiating Procedures

About 48 percent of the records came from plots that had been dropped at some earlier date, usually because of man-caused disturbance. Data from these plots were used to develop and "debug" the PSP system. We weeded out the many card duplicates by condensing all data for an individual tree onto a single card and adding any measurements that had not yet been punched.

Concurrently, we developed three programs (Fig. 1). A card-edit program (EDITD) checked the cards for certain kinds of frequent field crew errors in keypunching and in coding of tree description and crown class. The printout went to the research forester, who checked field sheets to reconcile the errors indicated. Corrected cards next were keypunched and inserted into the card decks. We sorted (DSORT)

[2] Programming details are available from the Biometrics unit, Moscow Forestry Sciences Laboratory, Moscow, Idaho 83843.

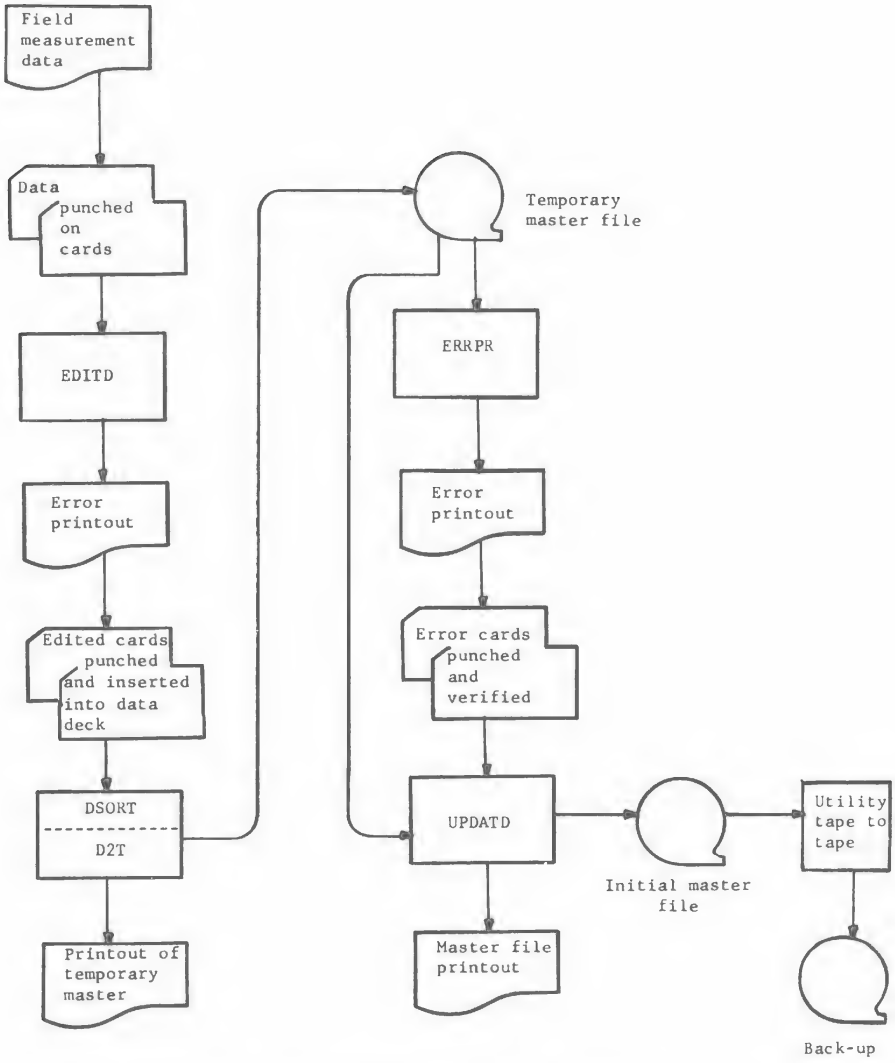

Figure 1. Flow chart for initiation of the Permanent Sample Plot System.

the decks in sequential order by plot and tree number by means of a sort algorithm written by IBM. Then, using a disk-to-tape program (D2T), we put them on a temporary tape master. At this point, careful reviews of data printouts for the deactivated plots revealed other kinds of errors in the entries that needed correction. Field crews occasionally made mistakes in measuring or recording tree diameters that resulted in an apparent negative growth rate or an apparent inordinate growth rate since the last measurement date. Also, we sometimes found that trees previously recorded as dead were still alive. To locate such errors, a tape edit program (ERRPR) was developed. (In

some instances, consolidation of the two edit programs, EDITD and ERRPR, may be warranted.) In addition to new data and data to be deleted, the corrected entries were keypunched and used as input data in the update program (UPDATD), which produced a final tape master file and a printout. For insurance purposes, a backup tape was made by using an IBM utility program.

Current System

PSP, as developed for the deactivated plots, gave a similarly edited and updated master file of the active plot data. However, because of their continuing nature, these plots required an open-ended data-handling system. Two programs were added to make field forms with features that inherently induce accuracy into the system (Fig. 2). FIELD makes forms from the master that list the two earlier measurements as well as identifying spaces for insertion of new measurements. Inclusion of previous records makes it easy for the field recorder to check compatibility of current data with old data. A spe-

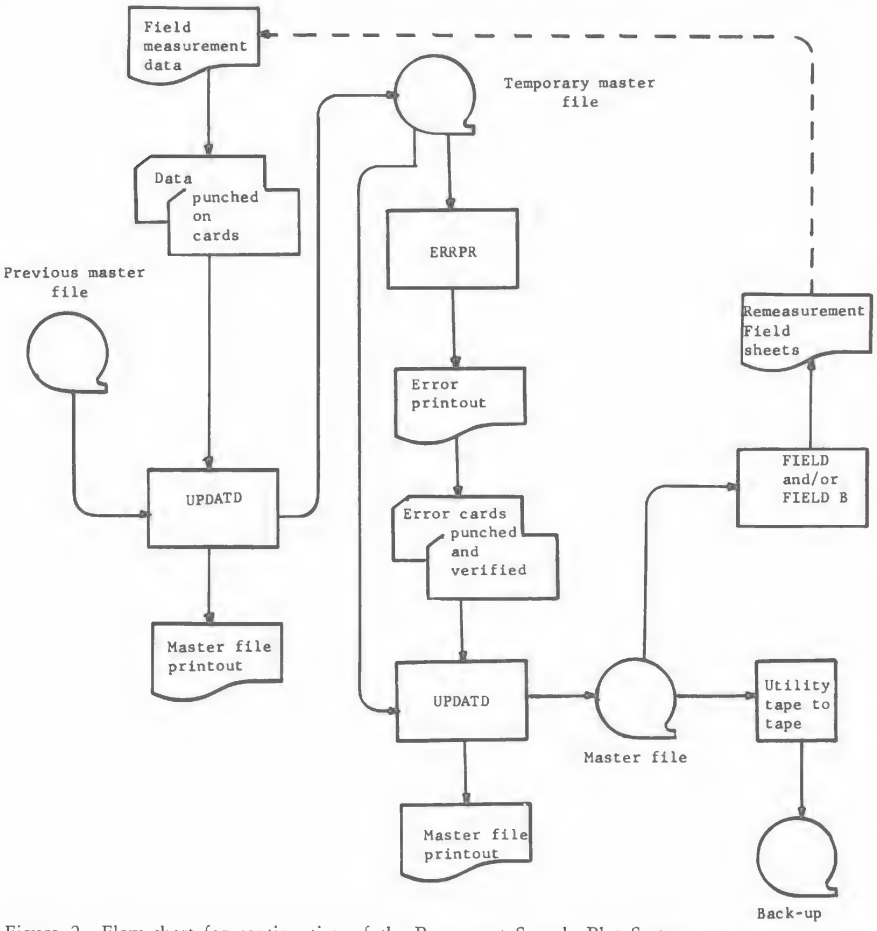

Figure 2. Flow chart for continuation of the Permanent Sample Plot System.

cial advantage of the computer-printed field sheets is that fewer of them are needed because tree data are more compactly arranged. Also, previously recorded dead trees are omitted, and keypunching instructions are simplified.

The second program, FIELDB, makes blank forms to be used when previously unmeasured trees are added through ingrowth or when new plots are first established.

Data Storage

Having the plot records on disk or tape facilitates fast retrieval and provides security against loss. In our case, tape storage was selected over disk storage because locally higher costs of the latter outweighed its benefits. We have provided security from inadvertent loss through the following decentralized storage arrangements: (1) the master file is stored in the computer library of a cooperating university, (2) a duplicate tape is kept in an off-line storage vault, (3) the original field recording sheets and a complete printout of the master are stored in local research files, and (4) the original data cards and error cards are on file in a Federal Record Center.

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Characteristics of Black Bear Dens on Long Island, Washington[1]

Abstract

Dens of 11 transmitter-equipped black bears *(Ursus americanus)* on Long Island in southwestern Washington were investigated. Preferred den sites were natural cavities under stumps or snags which could be used with little preparation. Adult bears denned in areas cut before 1955; yearlings denned generally in areas cut after 1966. Adult females collected greater amounts of vegetative material for nests than did yearlings.

Introduction

Black bears display considerable flexibility in selection of sites for winter dens. Erickson (1964) found bears in Michigan to den most commonly under stumps and logs or in holes in hillsides. Jonkel and Cowan (1971) reported that the preferred den site in Montana was in the base of a hollow tree, but they also found bears denned in rock caves and holes dug into the ground. Bears in Louisiana were observed to den in hollow trees in which the entrance to the den was above ground level (Taylor, 1971). Poelker and Hartwell (1973) followed the movements of a radio-equipped sub-adult female in western Washington and observed her to enter two dens in hollow logs, one in the base of a rotten stump and another in a natural cavity in the base of a bigleaf maple *(Acer macrophylla)*. Manmade structures used as den sites include drainage culverts (Barnes and Bray, 1966) and basements or foundations of buildings (Skinner, 1925; Jonkel and Cowan, 1971. Seven percent of dormant bears in a Michigan study were found in unsheltered depressions (Erickson, 1964). Wakefield (1969) in Pennsylvania states that only pregnant females reportedly require protective dens.

Erickson (1964) reported that females and juveniles more commonly lined their dens with vegetation than did adult males. He theorized that adult males enter dens later than other bears and thus suitable nest material was less available at the time they entered. Jonkel and Cowan (1971) found nest material in 10 of 31 dens examined. Three of the dens with nest material were occupied by females; sex of the occupants of the remaining seven was unknown.

Den site selection and den characteristics may vary between and within regions in

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response to differing requirements of the various sex and age classes of bears. These characteristics have not been investigated for black bears occupying the coastal areas of Oregon and Washington. The present paper reports on the selection of sites and characteristics of the dens of 11 transmitter-equipped bears in southwestern Washington; information on site selection only was provided by three additional adult male bears.

Study Area

The study was conducted on Long Island, a 1,953 ha island located in the southern end of Willapa Bay in southwestern Washington. The climate of the island is typically cool marine, characterized by mild winters and cool summers. Precipitation occurs principally as rain and averages 120 cm annually. Logging has dominated land-use of the island. Timber was harvested periodically between the turn of the century and 1968.

The island is located within the Picea Sitchensis Zone (Franklin and Dyrness, 1973), a belt of vegetation which extends along the coast of Washington and Oregon. Five major upland types were delineated on the island, based primarily on seral stage. Areas on the island logged between 1963 and 1968, approximately 565 ha (Type 1) were characterized by dense stands of shrubs. Salal *(Gaultheria shallon)* was the most prominent shrub, but evergreen huckleberry *(Vaccinium ovatum)* and red huckleberry *(Vaccinium parvifolium)* were abundant. Thick stands of young western hemlock *(Tsuga heterophylla)* characterized locales cut between 1952 and 1959 (Type 2, 455 ha). Brush species, principally salal, were still abundant and productive in these areas although restricted mainly to borders of secondary logging roads, skid trails, and numerous small openings. Sitka spruce *(Picea sitchensis)* was scattered throughout these stands and western redcedar *(Thuja plicata)* was common locally in more moist sites. Areas either partially logged or clear cut before 1935 (Type 3, 675 ha) were dominated by western hemlock with Sitka spruce a persistent member of each stand and western redcedar locally common. Less frequently, areas clear cut before 1935 supported nearly pure stands of mature red alder (*Alnus rubra;* Type 4, 100 ha). The understory of conifer and alder stands was generally open, with ferns, principally sword fern *(Polysticum munitum),* forming a dense ground cover in the alder stands. Shrub species were dense only in small openings in the conifer stands. The final vegetation type (Type 5, 140 ha) was dominated by virgin redcedar. The stand also included Sitka spruce and western hemlock. Densities of brush in the understory varied from light to moderate.

Methods

During the spring and summer of 1973, 16 black bears were captured and fitted with radio transmitters; 14 were still being monitored when they entered dens.

Our experiences, and those of Poelker and Hartwell (1973) also in the Northwest, indicated that with the exception of most sows with cubs, bears will leave their dens on approach by humans. Therefore, we visited only the dens of adult females and one yearling during the winter. The remainder of the dens were examined in the spring after the bears had emerged. Measurements were made of the maximum height and width of entrances, and the height, width, and length of chambers. Nests were measured when present, and the volume of nest material estimated. Entrance exposure was determined with a compass, and the degree to which the entrance was obscured by brush

within 60 cm was estimated. Diameter of a tree with a den was measured at breast height (dbh).

Results

Ten of the 12 dens were associated with dead trees. Six of these were under upright stumps, two under stumps which had been pushed over during logging, one under a fallen tree, and another under a standing snag (Table 1). The two remaining dens were associated with live trees and both occupied by a single yearling.

With one exception, dens of yearlings were in areas cut after 1966 (Type 1). All dens of adult bears (3+ years—no 2-year-olds were present), with the exception of the den of an adult female in a 1966 cut, were in areas either partially cut or clear cut prior to 1956. The female which denned in the 1966 cut moved from her den in early December. Additionally, the dens of three instrumented adult male bears were in areas cut before 1956. The transmitter on these males failed during the winter.

Four (40 percent) of the dens located on the ground were on slopes ($\bar{x} = 20$ percent, range = 11-39 percent). Two slopes had west exposures and the other two faced southwest. The average diameter of trees associated with the dens was 163 cm (sd 71 cm). Entrances to dens under upright stumps were formed by roots and those under overturned or fallen trees by the trunk and root mass. Dens of adult females more frequently had two entrances than did dens of yearlings. Entrances to three of four ground dens of yearlings were obscured by brush whereas entrances to dens of adult females were unobscured. The average maximum height of entrances to dens of adult females (38.4 cm) and yearlings (43.13 cm) did not differ significantly ($P < 0.05$, $t = 0.686$, $df = 11$). The mean maximum width of entrances to dens of yearlings (78.5 cm) was, however significantly greater ($P < 0.05$, $t = 3.528$, $df = 11$) than the mean width of entrances to dens of adult females (45.1 cm). Both sides of the den of the adult male, which was under a fallen tree, were open.

Chambers of dens under standing stumps or snags were formed by roots. Soil under the tree, which had been held by the roots, had either eroded or been dug out to form the chamber. Chambers of dens under overturned stumps were formed by the root mass and butt of the stump. Although chambers in dens of adult females appeared larger than those of yearlings, their height ($t = 0.335$, $df = 7$), width ($t = 0.628$, $df = 7$), and length ($t = 0.945$, $df = 7$) did not differ significantly ($P > 0.05$) from the yearlings.

Only three of 10 ground dens appeared to have been constructed or modified during fall 1973 prior to their use. Yearling male 7310 apparently had cleaned the chamber of the den he occupied, and increased the height of the entrance by approximately 7 cm by chewing on the root which formed the top of the entrance. Adult female 7307 dug in the chamber of her den but removed no soil from the den. Only one monitored bear, a yearling female (7314), constructed a den during the fall. She apparently formed the den by enlarging a natural cavity under a stump. A mound of soil approximately 6 liters in volume was found at the den entrance. Dens occupied by the remainder of the bears were either natural cavities which required no modification or dens that were constructed and utilized in previous years. Soil removed from the den before the fall of 1973 was found at entrances of two dens (7307, 7310). Six dens (7303, 7305, 7307, 7309, 7311, 7313) contained nest material from previous years.

Two of the dens on the ground contained no nest material (7301, 7308); however, the floor of the den of 7308 was covered with dried pieces of the decaying stump under which it was located. The two dens in trees were not examined for nest material. Greater amounts of nest material were found in dens of adult females than in dens of yearlings. Female 7305 collected additional nest material (40 liters) in the spring and made a bed outside the den immediately in front of the west-facing entrance. The most common materials used for nests were hemlock, sword fern, and salal. None of these dens were occupied the following winter (1974-75).

Discussion

The preference exhibited by bears for dens in natural cavities under stumps or snags probably is based on need and convenience. Such sites are readily available to bears and require little or no preparation. The principal function of the den in the Northwest appears to be protection from heavy winter rains. That only pregnant females would require the protection offered by a den or that bears on the island would den in unsheltered depressions such as those found by Erickson (1964) in Michigan seems unlikely.

Exposure of the slope or aspect of den entrance apparently did not influence selection of den sites. Craighead and Craighead (1972) attributed the selection by grizzly bears *(Ursus arctos)* of north-facing slopes on which to den, to the insulative qualities afforded by the greater accumulation of snow on these slopes. We found no evidence that adult females had removed brush immediately in front of entrances to their dens, suggesting that the presence of brush at den entrances was characteristic of the vegetation type in which the bear denned. Brush immediately in front of the den entrance may, however, have blocked rain from being blown directly into the entrances of dens of yearlings which were generally found in areas not protected by an overstory of trees. The small size of den entrances probably reduced the amount of rain entering a den and provided a more defensible position against attack by other bears.

The similarity between chamber size and entrance height of dens of adult females and yearlings may reflect the tendency for bears to occupy dens which had been constructed in previous years. The principal differences observed between dens of adult females, all of which were known to have given birth to cubs during the winter of 1973-74 (except 7307), and dens of yearlings was the vegetation type in which they were found and the amount of nest material used. Because the range of each bear included areas cut before 1956, as well as areas cut since 1966 (Lindzey and Meslow, in preparation), the tendency for yearlings to den in recently cut areas and adults to den in areas dominated by timber suggests a selection for certain vegetation types. Timbered areas apparently offered security to bears on the island. When confronted by a human or chased by another bear in the recently cut areas, bears we observed ran to the nearest stand of timber. Presumably, adult bears selected the most secure habitat in which to den. Timbered sites would be of particular value to females with cubs to protect. Yearlings may have denned in the more open, less secure areas to avoid contact with adult bears. The location of the two dens of 7315 in trees, the only yearling that denned in a timbered area, also probably minimized the chance of contact with other bears.

Dens on the island more frequently (80 percent) contained nest material than did dens in Michigan (39 percent: Erickson, 1964) or dens in Montana (30 percent: Jonkel

TABLE 1. Characteristics of dens and den sites of 11 black bears on Long Island in southwestern Washington.

Bear No.	Sex	Age[a]	Den Location	Vegetation type	No. of entrances	Aspect of entrance	Entrance height-width (cm)	Chamber height-width-length (cm)	Nest material (liter)
7310	M	1	Under overturned stump	1	1	NNW	28-66	44- 52-118	1
7311	M	1	Under upright stump	1	2	W/NE	41-97, 32-82	43- 54-112	10
7308	M	1	Under upright stump	1	1	W	49-45	109-122-170	0
7314	F	1	Under upright stump	1	1	E	42-101	72- 79- 90	9
7315A	F	1	In live tree[b]	3	1	—	—	—	—
B			In live tree[b]	3	1	W	—	—	—
						Yearlings	$\bar{x}$H =38.4 (sd 8.4) $\bar{x}$W=78.4 (sd 23.3)	$\bar{x}$H = 67 (sd 31.1) $\bar{x}$W= 77.5 (sd 31.9) $\bar{x}$L =122.5 (sd 33.9)	
7303	F	5	Base of snag	2	2	W/E	39-31, 39-45	62- 94-121	105[c]
7305	F	3	Under standing stump	2	2	W/SE	41-41, 32-56	52- 75-128	105
7307	F	5	Under overturned stump	1	2	N/E	56-42, 30-53	76- 58-115	45
7309	F	5	Under standing stump	3	1	NNW	42-32	68-122-165	70

TABLE 1. (Continued)

7313	F	9	Under standing stump	3	1	S	69-61	93- 97-187	90
						Adult females	$\bar{x}$H =43.2 (sd 12.9) $\bar{x}$W=45.1 (sd 10.9)	$\bar{x}$H = 70.3 (sd 15.3) $\bar{x}$W= 89.2 (sd 24.2) $\bar{x}$L =143 (sd 31.1)	
7301	M	3	Under fallen tree	3	open	—	—	—	0

[a] Age in years during Fall 1973
[b] Bear moved from site
[c] Includes material in nest at entrance (see text)

and Cowan, 1971). Because rainfall is much greater in this region, nest material that would insulate the bear from water which might enter the den may be of greater importance. The larger amounts of nest material used by pregnant females probably would insure the insulation of cubs from the ground moisture. A thick layer of nest material might also decrease the chance of a cub being hurt if the female should lie on it.

Intensive logging will decrease the availability of preferred den sites, especially as the time between subsequent cuts is shortened. However, because of the flexibility exhibited by black bear in the selection of den sites, perhaps a decrease in preferred den sites alone would not cause a corresponding decrease in black bear numbers.

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The Life History of the Side-Blotched Lizard, Uta Stansburiana Baird and Girard, in North-Central Oregon

Abstract

The life history of the side-blotched lizard, *Uta stansburiana,* was studied in Jefferson Co., Oregon. Most individuals reproduce when 10 months old, but a small percentage of the yearlings (late season hatchlings) are too small to reproduce in their first spring and breed for the first time when 20-22 months old. Mark-recapture data indicate that annual adult survival is about 30 percent. Most females produced one clutch per season, although a few may have deposited two clutches per season. Mean clutch size was 3.33. Clutch size was positively correlated with body size and negatively correlated with day-of-year. There were 175 utas/ha on the study area. The home range of mature males ($\bar{x} = 0.219$ ha, SE $= 0.06$, n $= 9$) was not significantly larger than that of mature females ($\bar{x} = 0.175$ ha, SE $= 0.04$, n $= 8$). Individuals did not appear to maintain rigid territories and are apparently less aggressive than has been reported for Texas utas. Data presented here and in the literature suggest that with increasing latitude and elevation utas have: (1) reduced seasonal fecundity (clutch frequency and clutch size are reduced), (2) greater longevity, and (3) delayed maturity in some individuals. Environmental correlates of changing latitude and altitude (differences in predator and competitor diversity, predictability of resources and growing season length) are briefly examined and discussed as possible selective agents in shaping life history strategies across populations of *U. stansburiana.*

Introduction

The side-blotched lizard, *Uta stansburiana,* ranges throughout much of the Intermontane Basin and low desert country of western North America, including all of eastern Oregon except for the extreme northeastern, mountainous portion of the state. The northernmost limit of the range is near Vantage, in central Washington.

Largely because of the efforts of Tinkle (1961, 1965, 1967a, 1967b, 1969a, 1972), Turner *et al.* (1970), and Tanner (1972), *U. stansburiana* is the best known lizard ecologically and demographically. With such a broad data base available for comparison, *U. stansburiana* is particularly attractive for further study since field-testable predictions concerning environmentally induced variations in life history can be formulated. Although *U. stansburiana* has been intensively studied at various localities in the southern part of its range, almost nothing is known of this species in the extreme northern portion of its range. We had hoped to complete a comprehensive demographic sudy in Oregon in order to test Tinkle's (1967a, 1969a) predictions as to the effects of shorter growing seasons on the life history of *U. stansburiana,* but we were forced

to abandon the project because of unanticipated moves by both of us. However, some useful data have been accumulated and are presented here.

Study Site

The study site is about 1.6 km below Lower Bridge on the west bank of the Deschutes River, Jefferson Co., Oregon. Here the Deschutes River cuts a deep canyon through the floor of the Columbia Plateau, leaving vertical cliffs up to 35 m high extending down to a boulder-strewn slope adjacent to the river. Utas can be found perched on rocks along the slopes, on the cliff-faces, and on the rim above the cliffs.

The site is in the Upper Sonoran Life Zone at 732 m (2400 ft) elevation. Average annual precipitation is 20 cm, much of it in the form of winter snow. Temperature averages 18 C in July and -2 C in January. The frost-free season is about 110 days, with frosts sometimes occurring as late as 22 May.

Two lizard-eating snakes, the striped whipsnake, *Masticophis taeniatus,* and the spotted night snake, *Hypsiglena torquata,* are common at the study site, as is the gopher snake, *Pituophis melanoleucus.* The northern Pacific rattlesnake, *Crotalus viridis,* occurs in this region, but none was seen at the study site. The racer, *Coluber constrictor,* occurs infrequently, and two garter snakes, *Thamnophis sirtalis* and *Thamnophis elegans* are found adjacent to the river, the latter species in greater abundance. The western fence lizard, *Sceloporus occidentalis,* is the only other common lizard at the site and seems to be spatially segregated from the utas. *S. occidentalis* is confined to the lower portion of the boulder-strewn slope, near the lush vegetation along the river bank, whereas utas are restricted to the drier upper portion of the slope, cliff faces and rim. The southern alligator lizard, *Gerrhonotus multicarinatus,* has been seen only once in the vicinity.

Seasonal Activity

The period of activity or growing season at the study site varies from year to year, depending on annual variation in temperature and snowfall. Annual variation in snowfall can be considerable in this region. Utas may be sporadically active as early as late March-early April after exceptionally mild winters and during warm springs, and as late as early October. For any given year the period of activity is not likely to be longer than 150 days. To the north in the Rattlesnake Hills of Washington, Rickard (1967, 1968) reported utas active from April to November in 1966, and from April to October in 1967, with low indices of activity during the earliest and latest months.

Age-Structure, Size and Growth

Tinkle (1967b) found that utas in Texas could not be aged accurately by size because hatchlings grew fast and broadly overlapped their parental cohort in size the following spring. Tinkle (1967b) also found size overlap between age-classes in Colorado. However, Turner *et al.* (1970) recognized two age-classes based on size in the spring months in southern Nevada and showed with known-age females that only 7.8 percent would be misassigned by size criteria. Tanner (1972) also found distinct age-classes in nearby southern Nevada populations, and we believe age-groups are discernible in the spring in Oregon.

The size range of 62 males sampled in May 1973 was 32-53 mm SVL (= snout vent length), with only four males less than 40 mm. By June 1973 the size range of 66 males was 40-53 mm, with two apparent size-classes (Figure 1). Cumulative frequency distribution of sizes of males (method of Harding, 1949) in June also indicates two size-classes with means of 42.9 mm (SD = 1.53) and 48.4 mm (SD = 1.80) (Figure 2). We believe these size-classes represent yearlings and older groups respectively, with 42.4 percent of the sample consisting of yearlings. A sample of 76 males collected between 25 July and 13 September 1973 consisted of only one group of mature males 42-52 mm (71.1 percent of sample) and a group of yearlings 22-36 (Figure 1).

Sixty females collected between 3 May and 26 May 1973 ranged in size from 34 to 48 mm. Although a histogram of sizes (Figure 3) does not show two distinct size-classes, graphical analysis (Figure 4) indicates two size-classes with mean SVL's of 36.0 mm (SD = 2.0) and 43.8 mm (SD = 2.5) respectively. These size-classes probably correspond to age-classes in the manner discussed above for males, with age-classes less distinct for females because they attain a smaller average size than males. Ninety-two females collected 26 May to 23 June 1973 had a size range of 40-49 mm (SD = 2.15) (Figure 3) with no recognizable age-classes. Females (71) collected 25 July to 18 September 1973 consisted of two groups (Figure 3): young-of-the-year (22-36 mm, 32.4 percent of the sample) and older females (41-48 mm).

It can be argued that the bimodality in size of males and females captured in the spring results from two peaks in egg-laying the previous year. If this is true, the modes would not represent year-classes as discussed above. However, there is no bimodality in the size distribution of young-of-the-year captured in September, as would be expected if the modes result from early and late clutches. Further evidence that the two size-classes of adults are not products of early and late clutches is available from recapture data. Eleven of the 36 adults (30.6 percent) marked during the breeding season of 1973 survived through the 1974 breeding season (Table 1). The size and growth of the smaller adults marked in 1973 and recaptured in 1974 correspond very closely with the size and growth predicted from the histograms (Figures 1, 3; Table 2) if the modes are considered to be year-classes.

From these observations we estimate that males hatched at 22 mm at the end of July grow to about 32 mm by mid-September (0.22 mm/day) just prior to hibernation. Growth resumes the following spring (mid-April) so that by mid-June when they are about 13 months old (from the time they began life as a deposited egg) they average 44 mm; hence the growth rate from mid-April to mid-June was 0.20 mm/day. By mid-June the following year when the surviving males are about 25 months old, they will average 49 mm for a growth rate during their second year of life (150-day growing season) of only 0.03 mm/day. Females follow the same growth pattern in their first season, but they grow somewhat slower than males in their first spring (0.17 mm/day). Females grow much slower than males in their second year and by late May or early June, first and second year size-classes cannot be readily distinguished. One would hope for growth data on known-age, marked animals to support these growth estimates based on size-classes. Unfortunately, we have such data for only 11 utas known to have lived at least two years (Table 1). Few as these data are, they tend to substantiate our interpretation of size-class data. Within the 1973 growing season, eight mature males grew

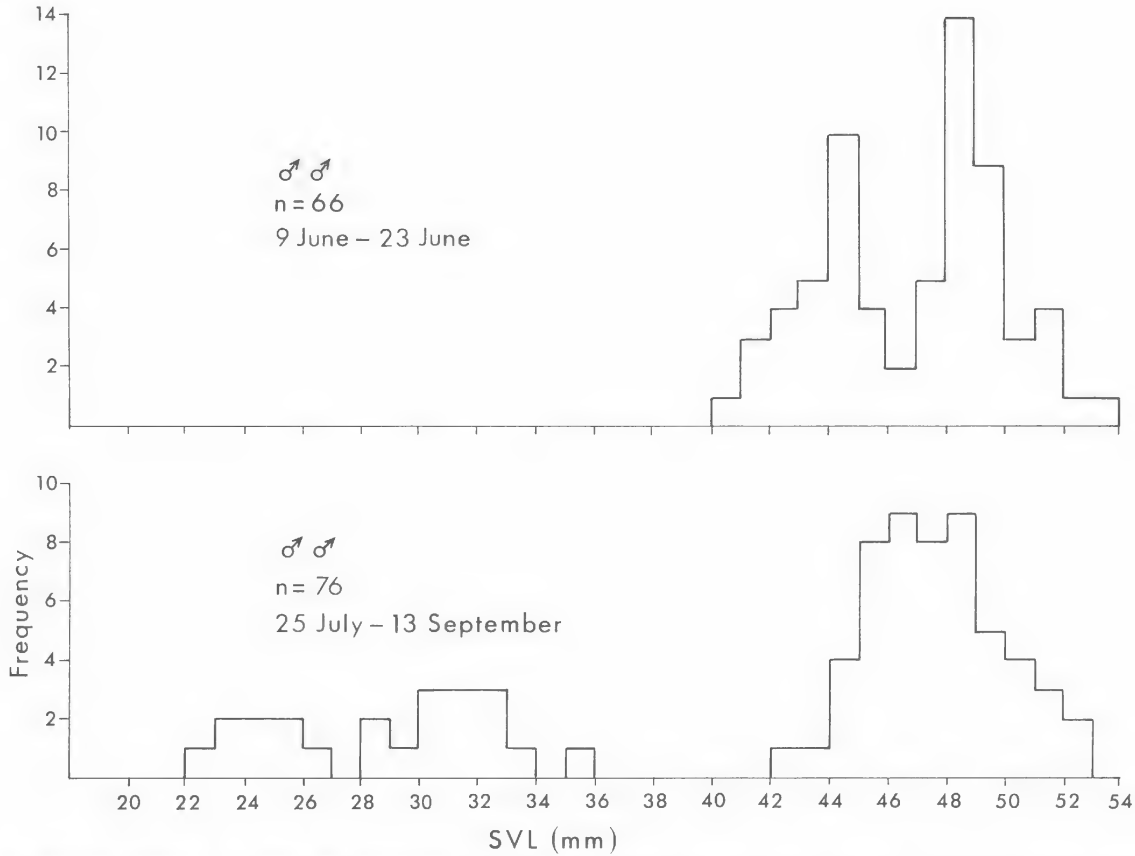

Figure 1. Size-frequency histograms for male utas collected in 1973 near Lower Bridge, Jefferson Co., Oregon. In the spring, two size-classes of adult males are apparent; in mid to late summer only one size-class of adult males is evident, in addition to young-of-the-year (<36 mm SVL).

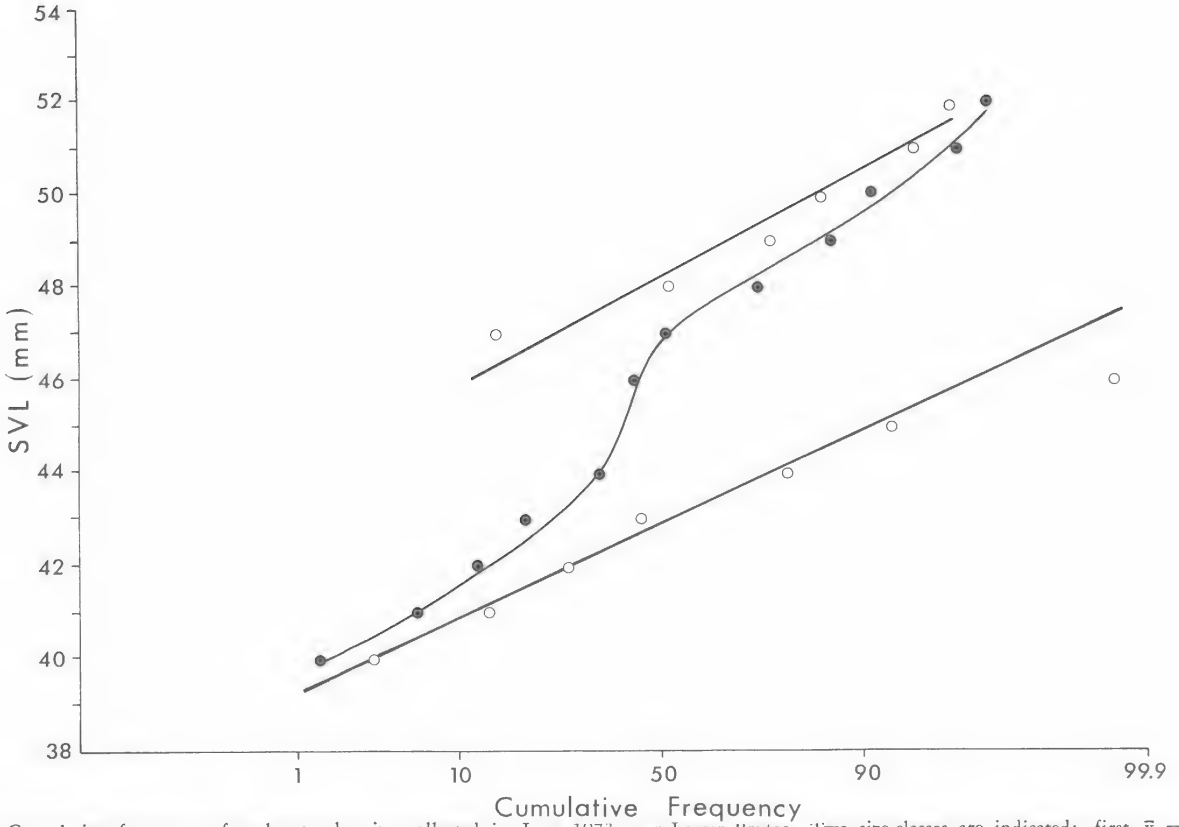

Figure 2. Cumulative frequency of male utas by size collected in June 1973 near Lower Bridge. Two size-classes are indicated: first, $\bar{x} = 42.9$ mm SVL, 42.4 percent of sample, second $\bar{x} = 48.4$ mm SVL, 57.6 percent of sample, $n = 66$.

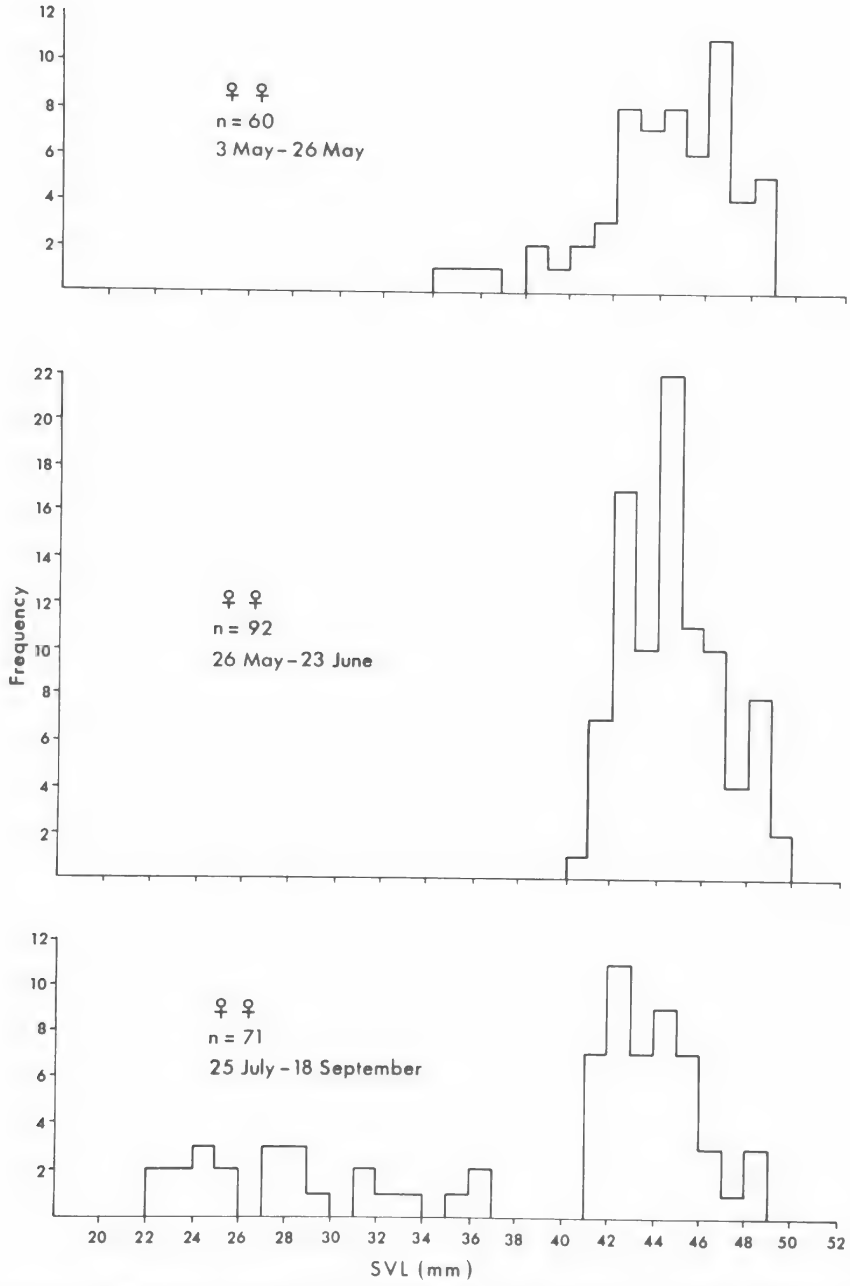

Figure 3. Size-frequency histograms for female utas collected in 1973 near Lower Bridge, Jefferson Co., Oregon. In early spring (upper histogram) the distribution suggests two broadly overlapping size-classes, which is verified by probability distribution (Fig. 4). By early summer (middle) the two size-classes cannot be distinguished, and by late summer (lower) young-of-the-year and one size-class of adult females are present.

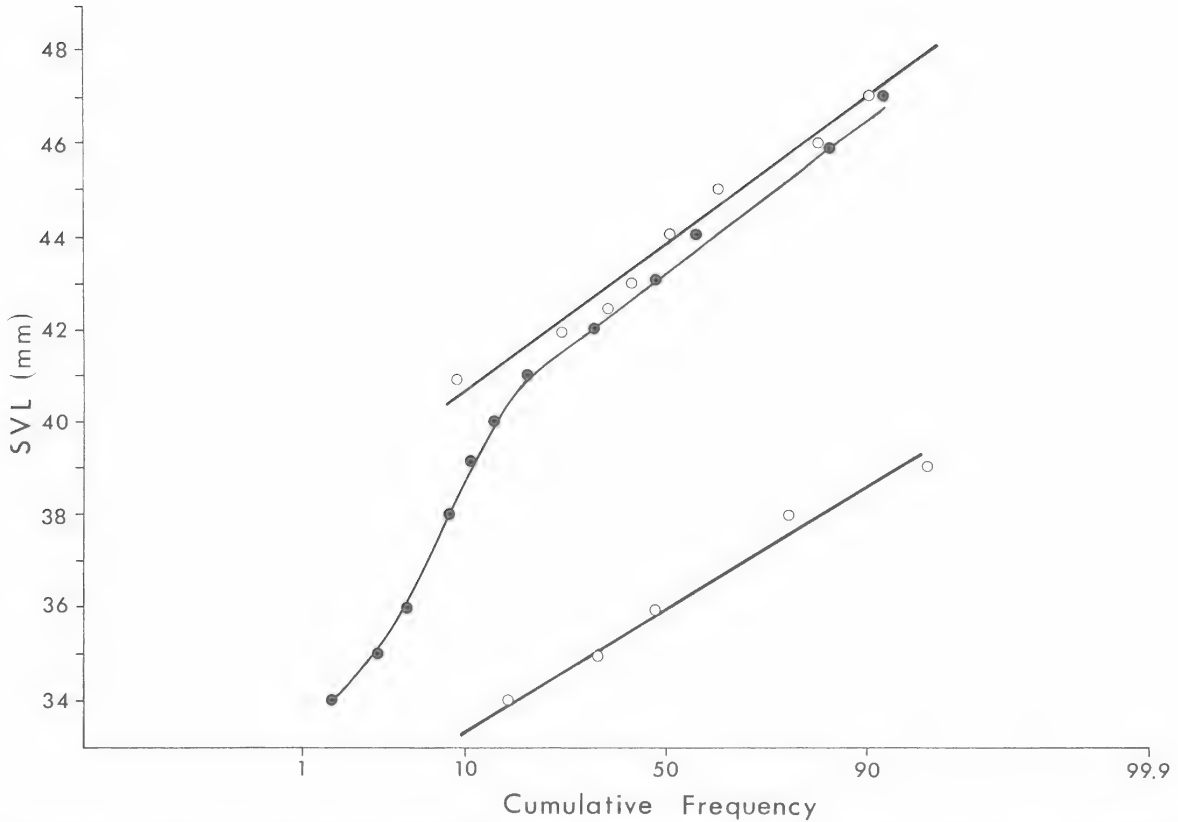

Figure 4. Cumulative frequency distribution of females by size. Data from upper histogram of Fig. 3. Two modes are distinguished: first, $\bar{x} = 36.0$ mm SVL; second $\bar{x} = 43.8$ mm SVL.

at an average rate of 0.035 mm/day (SD = 0.033), a value close to that predicted above for second-year males based on size-classes. Seven mature females did not increase in SVL during the 1973 reproductive season. However, one small female which apparently did not reproduce in 1973 grew from 40 to 45 mm SVL in 54 days (17 May to 11 July).

The smallest sexually mature male was 40 mm; the smallest mature female was 41 mm, although a few were still immature at 42 and 43 mm.

Male Reproductive Cycle

Multiple regression of volume of testes on SVL, body weight, and day-of-year shows that day-of-year is the best predictor of volume of testes (significant at $F_{.999}$, $r = -0.853$, $r^2 = .728$, $n = 38$). SVL has a significant ($F_{.99}$) additional effect on volume of testes but only increases r^2 to 0.821.

Most males bred in their first spring when 9-12 months old, but a few males did not. Of 88 males collected between 3 May and 10 July 1973, seven or 7.95 percent did not breed that season as evidenced by undeveloped testes and thin, straight, translucent vasa deferentia. These were the smallest of the yearling males, ranging in size from 33 to 45 mm ($\bar{x} = 39.9$ mm), and they represented 18.76 percent of the yearling males.. The two largest non-breeders (42, 45 mm) were captured 10 July at the end of the reproductive season, and they probably measured less than 40 mm in May when the two smallest non-breeders (33, 36 mm) were caught.

Among breeding males, the vasa deferentia were highly convoluted, thick, and

TABLE 1. Growth of utas captured in 1973 and recaptured in 1974.

Animal No.	sex	Date marked 1973	Date recap. 1974	Elapsed time (mo.)	Initial SVL (mm)	Final SVL (mm)	△SVL	Initial weight (g)	Final weight △ (g)	△ g
6B	male	5-17	6-13	13.0	44	48	4	2.92	3.41	0.518
9B	male	5-17	6-2	12.5	39	47	8	1.97	—	—
10B	male	6-9	6-11	12.0	46	49	3	2.70	3.41	0.710
13B	male	7-10	6-13	11.0	48	49	1	—	3.25	—
20B	male	7-11	6-2	11.0	49	51	2	3.53	—	—
1A	male	5-16	6-11	13.0	48	49	1	3.58	3.33	*
5A	male	5-28	6-11	12.5	42	48	6	2.37	3.66	1.290
12B	female	6-9	6-11	12.0	41	46	5	1.84	3.23	1.390
19B	female	7-11	6-13	11.0	44	46	2	2.29	—	—
13A	female	7-21	6-11	10.5	41	44	3	—	2.61	—
11A	female	6-10	6-11	12.0	44	46	2	2.79	3.12	0.330

* Negative value because of tail loss.

TABLE 2. Summary of sizes of June utas in Oregon (SVL in mm).

	Males		Females	
	1 year old	2 years old and older	1 year old	2 years old and older
$\bar{x}$	42.8	48.4	41.9	45.4
Stand. Error	0.29	0.22	0.15	0.23
Range	37.8-45.2	46.0-52.7	39.5-42.8	43.0-49.3
n	33	46	26	57

opaquely white from 3 May until 23 June, indicating potential for breeding throughout this period. During the last week of June and the first week of July the testes regressed and the vasa deferentia became thinner and began to clear. By late July the testes were minimum size, and the thin, clear vasa deferentia were not highly convoluted. The male reproductive organs remained quiescent throughout late summer and fall. The reproductive season for males is estimated to be 65 days, extending from the last week of April to the end of June.

Regression of fat body length on SVL and day-of-year gives day-of-year as the best predictor of fat body length ($F_{.999}$, $r = 0.482$, $r^2 = 0.233$, $n = 388$). SVL also has a significant ($F_{.999}$) correlation and when added increases r^2 to 0.457. For both sexes, fat bodies were small during the reproductive season and enlarged during the post-reproduction season, as reported by Tinkle (1967b) for Texas utas.

Female Reproductive Cycle and Fecundity

Of 55 mature females collected from 3 May to 26 May (our earliest sample), 52.9 percent had ovarian eggs, 43.6 percent had oviductal eggs, and 3.6 percent were spent as indicated by the presence of corpora lutea (Figure 5). We interpret these percentages to mean that very few females are capable of laying a first clutch until the last week of

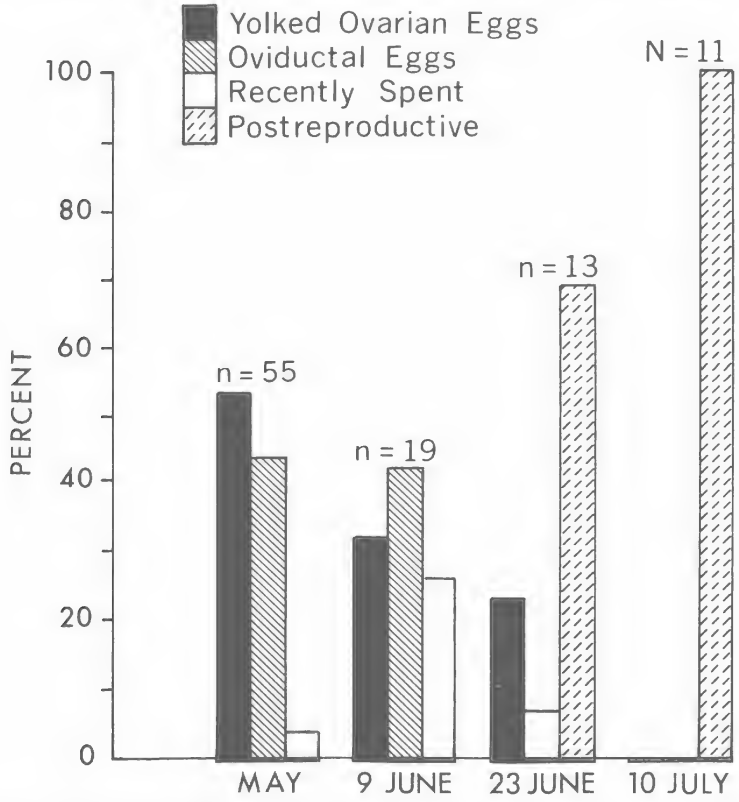

Figure 5. Reproductive condition of mature females through the 1973 reproductive season.

May. If the developmental time is 60-70 days as suggested by Tinkle (1967b), then this interpretation is confirmed by the first appearance of young on 25 July 1973. Of 19 females collected on 9 June 1973, six had small (4 mm diameter) ovarian eggs, eight had oviductal eggs (6 shelled, 1 with shell forming, and 1 unshelled), and five were recently spent. On 23 June, one female was recently spent, three had shelled oviductal eggs, and nine others had quiescent ovaries (atretic and/or undeveloped follicles). On 10 July 1973, 11 females had inactive ovaries (two with nearly resorbed atretic follicles). From these observations we believe that the last date for egg laying was near 1 July 1973. Utas of hatchling size were collected as late as 14 August 1973, and a single uta 2 mm larger than hatchling size (22 mm) was caught 13 September 1973. If this animal grew 0.2 mm/day, it must have hatched sometime near 3 September, which would correspond to the estimated last laying date (1 July + 65 days = 3 September).

Clutch frequency is the most difficult reproductive parameter to measure in multiple-clutched lizards, and there is evidence that clutch frequency varies from season to season in *Uta* (Turner *et al.,* 1970), and with the size of the female at the beginning of the reproductive season (Tinkle, 1967b; Turner *et al.,* 1970). Of 98 females sampled during the reproductive season of 1973, 15 or 15.3 percent showed no evidence of active ovaries. These inactive females ranged in size from 34 to 43 mm, $x = 39.6$ mm. The larger individuals (40-43 mm) were collected at the end of the reproductive season and were probably less than 40 mm at its onset. It was questionable as to whether another eight (8.2 percent) females would have laid in their first reproductive season. Their ovaries were inactive when collected early in the reproductive season but they were large enough (40-43 mm) so that they may have been able to produce a late season clutch had they not been collected.

Although equivocal, our observations on females suggest the following. The reproductive season for females in 1973 extended from 20 April to 1 July (70 days), although only a few females laid eggs after 23 June. Between 15 and 23 percent of the females (small yearlings) did not reproduce in 1973. Some of the larger yearlings, and perhaps some older females, produced only one clutch in 1973. If 31 days is enough time to yolk a second clutch (and it may be, according to Turner *et al.,* 1970), a few females may have deposited two clutches. It is highly unlikely that any female deposited three or more clutches. This conclusion is in accord with Parker and Pianka (1975), who stated that northern utas deposit only 1-2 clutches per female per season.

The following data on clutch size were taken from preserved specimens collected in 1973 and 1974. There were no significant differences between the two years so the data were pooled. Mean clutch size was 3.33, SD = 0.71, SE = 0.08, range = 2-5, n = 87. The mean number of corpora lutea was 3.36, SD = 0.67, SE = 0.09, n = 58. The difference between mean clutch size and mean number of corpora lutea is not significant. There was a significant difference ($P<0.05$) between the number of corpora lutea in the left and right ovaries: $\bar{x}$ left = 1.57, SD = 0.56, n = 58; x right = 1.80, SD = 0.51, n = 60. However, there was no significant difference between the number of eggs in the left and right oviducts.

Regression of clutch size on SVL is significant ($F_{.99}$, $r = 0.439$, $r^2 = 0.193$, n = 87). As expected from this relationship, yearling females lay significantly ($P<0.05$) fewer ($\bar{x} = 3.00$, SE = 0.09, n = 39) eggs than older females ($\bar{x} = 3.48$, SE = 0.10,

n = 52). Also, the clutch size was significantly ($P<0.05$) larger early in the reproductive season than later: May, $\bar{x} = 3.39$, SE = 0.10, n = 46; June, $\bar{x} = 2.28$, SE = 0.14, n = 17. This difference did not depend on body size, and the relationship is identical to that reported for Texas utas (Tinkle, 1961) and utas in southern Nevada (Turner *et al.*, 1970).

Table 3 lists egg measurements for three females with term eggs. The data suggest that larger clutches may be associated with smaller egg sizes, a relationship also indicated by Tinkle (1967b) for Texas utas. Further evidence for this relationship is available. Volume of shelled, oviductal eggs is significantly ($F_{.99}$) and inversely correlated with clutch size in 44 females ($r = -0.464$, $r^2 = 0.215$). Addition of SVL to the equation is not significant at $F_{.95}$. Vitt and Ohmart (1975) reported similar results for *Urosaurus graciosus* in Arizona.

Density and Home Range

Our density estimates are of limited value because we are unable to report annual variation or relate the density to demographic phenomena. A Schnabel estimate of the density on 2700 m^2 was 24 utas with a 95 percent confidence interval of 11.94 — 42.41 for 22 July 1973, just before the young-of-the-year appeared. This density converts to 175 utas/ha or 71 utas/acre, a value within the range of densities reported by Tinkle (1967b) for June-July in SW Texas for two populations and three different years (36 - 109 utas/acre).

We used a probability density function (A_3 of Jennrich and Turner, 1969; 95 percent confidence interval) to estimate the home ranges of nine males and eight females with 2-4 recaptures/uta within the 1973 reproductive season. Males had a mean home range of 0.219 ha (SE = 0.06) and females had a mean of 0.175 ha (SE = 0.04). Although males have a larger average home range than females, the differences are not statistically significant because of the great variance in home range size between individuals. This is in contrast to the low variance in home range size reported by Tinkle (1967a) and Tinkle and Woodward (1967) for utas in Texas and Colorado. We believe the higher variance in Oregon utas is related to differences in aggressive behavior and habitat heterogeneity (see below).

TABLE 3. Egg sizes for utas from Oregon; weight in grams, lengths in mm; all collected 11 June 1974.

Specimen	SVL	Live weight	Clutch size	Egg length	Egg width	Egg weight	Total clutch weight	Total room dry wt.	Total oven dry wt.
RAN 15901	44.8	2.736	3	9.9	6.5	0.206			
				11.1	6.2	0.222			
				11.3	6.2	0.221	0.649	0.313	0.308
RAN 15908	47.9	3.785	5	10.5	6.7	0.173			
				9.9	6.2	0.167			
				10.8	6.4	0.169			
				9.7	6.7	0.166			
				10.2	6.4	0.173	0.848	0.494	0.478
RAN 15916	46.2	2.964	4*	11.4	6.7	0.227			
				11.7	6.3	0.245			
				10.7	6.6	0.212	0.684	—	—

* One egg was destroyed before measured.

Tail Breakage

It is reasonable to assume that the probability of encountering a predator increases with age, and therefore the frequency of broken tails should increase with size. Our estimates of the frequency of broken tails may be too high. Some few lizards included in the sample may have lost their tails because of previous attempts by us to capture them. However, we believe the error is small and would not alter our conclusions. Thirty-seven of 113 males (32.7 percent) had broken or regenerating tails. When divided into small (<45 mm) and large (>45 mm) size-classes, $16/57 = 28.1$ percent of the small and $21/56 = 37.5$ percent of the large males had broken tails. Forty-two of 122 females (34.4 percent) had broken tails. Small females (<43 mm) had $24/47 = 33.8$ percent and large females (>43 mm) had $18/51 = 35.3$ percent broken tails. Although the change in break frequency is in the predicted direction for both sexes, the differences are not significant, based on 95 percent confidence intervals for binomial distributions. Tinkle (1967b) found no difference in break frequency between males and females in Texas, and this also seems to be true in Oregon.

Pianka (1967) reported that four out of five species of lizards, including *Uta,* had fewer broken tails in northern populations than in southern populations. In addition, Parker and Pianka (1975) reported that the combined frequency of broken tails in ten northern populations of *Uta* was 11.5 percent lower than for 12 southern populations. These authors thought that the increased frequency of broken tails in southern latitudes resulted from increased predation pressure because of the increased diversity of predators in southern deserts. However, our data do not support this explanation. The frequency of broken tails for both sexes in Oregon is nearly the same (33.6 percent) as reported by Tinkle (1967b) for Texas utas (30.0 percent) even though these two populations are very far apart latitudinally.

As pointed out by Tinkle (1972) and Tinkle and Ballinger (1972) tail-break frequencies can be compared meaningfully only if adjusted to account for generation time and active time. Oregon utas have a longer generation time than Texas utas, but a shorter active season because of the severe winters. Considering both generation time and active time per year, Oregon and Texas utas may be exposed to predation for nearly equal amounts of time. Since we lack a precise estimate of generation time for the Oregon population this possibility cannot be tested.

Causes of Mortality

Two lizard-eating snakes, *Hypsiglena torquata* and *Masticophis taeniatus,* were common at the study site. We found a large female uta in the stomach of a *H. torquata* and observed *M. taeniatus* stalking utas on the cliff-face. We assume these snakes feed heavily on utas since the only alternate lizard prey at the site is *Sceloporus occidentalis* which is not as abundant as *U. stansburiana.*

Winter freezing seems to be a major cause of mortality. We frequently found remains of utas in cracks on the cliff-face where they apparently had aggregated to hibernate. In one crack, exposed by prying loose an exfoliating slab which measured 2.5 x 3.0 feet in surface area, the senior author found 567 uta skeletons and mummies. These remains probably represent an accumulation over several years, but, even so, a remarkably high winter death rate is indicated.

Aggression

We often observed mature individuals of both sexes close together on the same boulder with little or no obvious interaction. Head-bobbing encounters were uncommon and briefly executed when they occurred. Seven adult males observed on the cliff-face, near the rim, in a small area about three meters across, although evenly spaced, showed no overt acts of aggression. Mature females seemed equally unaggressive. On three different days, five females were seen within an area of about 4 m^2 with no noticeable interaction. The only aggressive act observed was when an immature female approached a large, gravid female. The latter bit and chased away the former. These observations contrast with the highly aggressive situation observed by Tinkle (1967b) in Texas utas, but may be similar to observations of reduced aggression in Colorado (Tinkle, 1967b, 1969a; Tinkle and Woodward, 1967). Tinkle (1969a) hypothesized that the relatively high aggressiveness in Texas utas resulted in mutually exclusive territories, and was adaptive because individuals in Texas have only one chance to reproduce and lose nothing by increasing their reproductive effort through high aggression; whereas individuals in Colorado may have a chance to breed in a second year and hence may increase their fitness by submissive behavior. This latter situation could lead to social hierarchies (Colorado) as opposed to rigid territoriality (Texas), as suggested by Tinkle (1969a). We believe this hypothesis is reasonable, but also think that habitat heterogeneity may play a role. At Tinkle's Texas locality, utas are largely arenicolous and occupy flat or two-dimensional habitat. In Colorado and Oregon, utas are saxicolous with extremely broken, three-dimensional habitats. The added vertical component, plus the extremely patchy distribution of favorable basking and feeding sites, might make mutually exclusive territories difficult to maintain but would not preclude evolution of social hierarchies.

Sexual dichromatism is marked in Texas but less evident in Colorado (Tinkle, 1969a). One might therefore expect small sexual differences in color in Oregon utas if dichromatism is related to social structure, but such is not the case. Males are brightly colored in contrast to females and even to a greater degree than is found in the Texas utas (Tinkle, personal communication). The reasons for this sexual dichromatism are far from clear, since in Oregon there are few sympatric species and hence no need for greater sexual discriminatory powers to eliminate gamete wastage by interspecific courtship.

Activity

Temperatures fluctuated markedly through a 24-hour period during the summer at the study site. For instance, the minimum night-time air temperature on 28 May 1973 was −1.0 C whereas the maximum that day was 24 C. The mark-release plots were on east-facing slopes exposed to the early morning sun. We saw few lizards on the opposite side of the canyon which remained in the shade through the early morning. The earliest activity on the plots was at 0830 when utas could be found perched on the sunny side of large boulders which were still cool. Peak activity occurred between 1000 and 1100, but had completely stopped by 1230. Utas became active again in the late afternoon, but none was active after the shadows fell at about 1830. These observations are contrary to the statement by Parker and Pianka (1975) that northern utas show continuous diurnal activity.

Discussion

Tinkle (1967a), on the basis of what he had learned of the demography of *Uta* in Texas, predicted that in the northern portion of its range *Uta* would have: (1) a shorter reproductive season, (2) lower natality, and (3) greater longevity. Tinkle (1967b, 1969a) tested and confirmed his predictions for *Uta* at higher elevation and latitude in Colorado. He also found that only about 40 percent of the summer hatchlings in Colorado reached sexual maturity by the beginning of the breeding season the following spring, whereas all Texas juveniles had matured by this time.

Turner *et al.* (1970) presented data for utas in southern Nevada at higher elevations and slightly higher latitude compared to Tinkle's Texas populations. Their results indicate that as in Colorado, life expectancy is greater and natality lower than in Texas.

Tanner (1972) compared *Uta* populations at equal latitudes but different elevations (1219 vs. 2280 m, Table 4) in southern Nevada and found that along with the shorter growing season at higher elevations, there was a higher percentage of older adults, and the average and maximum adult sizes were larger than at lower elevations. The earliest hatchlings at the high elevation locality were found on 17 July compared to 25 June at the lower sites, indicating a shorter reproductive season and perhaps fewer clutches per season at the higher site. Tanner (1972) concluded that with increasing elevation utas (1) live longer, (2) attain larger size, and (3) as a result of larger size have more eggs per clutch.

The elevation of the Oregon site is lower (731 m) than those considered so far, but it is at a much higher latitude. Utas live longer in Oregon, compared to Texas, but they do not attain larger size and do not increase clutch size, in contrast to Tanner's (1972) results for populations at very high elevations in Nevada. Per season fecundity is relatively low in Oregon, and age at maturity is delayed a full year in some individuals.

The data summarized in Table 4 indicate an inverse correlation between seasonal fecundity (clutch size times clutch frequency) and average adult life expectancy, a relationship already shown by Tinkle (1969b) to be true of lizards in general. It is intuitively reasonable that such an inverse relationship should exist, at least for some subsets of life history strategies. Perhaps of greater interest to biologists, however, is the identification of environmental factors which might select for shifts in this relationship across populations.

The five populations summarized in Table 4 occur across a broad range of altitudes and latitudes. Changes in the life history of *Uta* which are apparently correlated with increasing altitude and/or latitude are: (1) reduced per season fecundity (both clutch size and clutch frequency are reduced), (2) greater longevity, and (3) increased percentage of individuals that do not breed in their first year. Obviously altitude and latitude per se cannot affect these life history characteristics. Environmental correlates of changing altitude and latitude which may alter selection pressures in life history parameters are:

low altitude and/or low latitude	high altitude and/or high latitude
1. higher predator diversity	lower predator diversity
2. many competing species	fewer competing species

3. resource levels more predictable		resource levels less predictable
4. longer growing season		shorter growing season
5. longer reproductive season		shorter reproductive season

Theoretically, reduced predation in northern and high elevation populations of *Uta* could explain in part the higher average life expectancy in these populations. Total predation could be reduced by decreased predation rate, decreased exposure time to predation, or both. Pianka (1967, 1970) and Parker and Pianka (1975) thought that the lower diversity of lizard predators in the north would result in reduced predation pressure (rate) and that the lower frequency of broken tails in northern populations was evidence that this occurred. However, although there are fewer species of lizard-eating snakes at higher latitudes (Pianka, 1967; Arnold, 1972), this does not necessarily mean the predation rate is reduced, especially since there are also fewer species of lizards to serve as alternate food sources. Also, such indirect evidence from tail-break frequencies is not compelling because the frequencies were not adjusted to account for activity time and because of other unwarranted assumptions concerning tail loss in lizards (*e.g.,* equal predator efficiency across populations). If total predation is reduced in northern utas, as seems likely, reduced time exposed to predation (shorter active season) is a more plausible explanation than reduced predation rate caused by lower predator diversity.

TABLE 4. Comparison of data for five *Uta* populations.*

	Texas	Colorado	Nevada (Rock Valley)	Nevada (Rainier Mesa)	Oregon
Elevation (ft.)	2900	≅ 4250	≅ 4250	7840	2400
Length of growing season (days)	215	175	≅ 225	≅ 200	110-140
Length of reproductive season (days)	121-141	120	135	—	70
Habit	arenicolous	saxicolous	—	—	saxicolous
Sexual dichromatism	high	low	—	—	high
Aggressiveness	high	low	—	—	low
Social Structure	territorial	dominance	—	—	dominance (?)
Density (individuals/acre)	36-109	17.5	24	10	71
Male home range (acres)	0.50	0.27	—	—	0.54
Female home range (acres)	0.17	0.23	—	—	0.43
Hatchling size (mmSVL)	22	≅ 22	≅ 22	≅ 22	22
Size range mature males (mm)	40-60	42-	—	40-56	40-53
Size range mature females (mm)	40-60	37-	—	—	41-49
Average size adult males (mm)	—	—	—	49	48.4
Average size adult females (mm)	48.9	42.8	—	—	45.4
Clutch size	≅ 4.0	3.20	3.5-4.5	4.85	3.33
Clutch frequency	3-5	3	3-5	—	1-2
% males fail to breed first season	0.0	<25	—	—	=19.0
% females fail to breed first season	0.0	<25	—	—	=47.0
% males 2 years old and older	7	33	28	36-65	57.6
% females 2 years old and older	7	33	28	36-65	69.4
Date hatchlings appear	20 June	25 July	25 June	17 July	25 July

*Texas and Colorado (Tinkle 1961, 1967a, b, 1969a; Tinkle and Woodward, 1967)
Oregon (this study)
Nevada — Rock Valley (Turner *et al.,* 1970 and references)
Nevada — Rainier Mesa (Tanner, 1972)

Utas compete with fewer species of lizards at higher latitudes and elevations. Although interspecific competition must be reduced in these populations, nothing is known about resource levels and the intensity of intraspecific competition. Theoretical considerations are complex and beyond the scope of this paper.

As argued by Murphy (1968), an environment in which juvenile mortality is highly variable from year-to-year and unpredictable is likely to select for increased longevity and iteroparity.[1] It is reasoned that individuals which reproduce in more than one year have a higher probability of leaving descendants than semelparous or short-lived individuals, if survival of young is likely to be low or nil in some years. It is possible to examine indirectly the predictability and variation in resource levels, such as food, which are likely to influence juvenile growth and survival. Utas depend primarily upon insects for food. In deserts, grasslands, and other arid regions, insect abundance varies directly with primary production, which is in turn governed by the amount of annual precipitation (Rosenzweig, 1968; Brown, 1973). Predictability of the amount of annual precipitation should then be a crude measure of the predictability of good and bad years for juvenile growth and survivorship. Pianka (1967) showed by time-series analysis that seasonal and annual variation in precipitation is less predictable in the northern Great Basin desert than in the southern Sonoran and Mojave deserts. Wiens (1974) did similar analyses for grassland and shrub-steppe stations and found that the shrub-steppe and Palouse Prairie, both northern habitat types, had unpredictable monthly distribution of precipitation at lag intervals of 2-10 months. Furthermore, he found that the yearly pattern of precipitation is also less predictable in these two regions than in more easterly and southerly arid environments. He stated that "shrub-steppe stations especially lack well-defined repetitive precipitation patterns." Most of the northern portion of the range of *U. stansburiana* is in Wiens' shrub-steppe region. If northern utas are unable to predict good years for production of young, then selection will favor increased life expectancy and iteroparity, which may be achieved by selection for seasonally reduced reproductive effort (Hirshfield and Tinkle, 1975). While these considerations fit well with observed variation across populations of *Uta,* alternative explanations are available.

The active season of *Uta* is divided into an early period of reproduction and a late period of growth and fat accumulation. Utas grow little if at all during the reproductive season (Tinkle, 1967b). Therefore a late season period during which there is no reproduction is essential if utas are to increase body size and store enough energy to overwinter and reproduce early the following spring. Furthermore late season reproduction is precluded because late clutches will not hatch before the arrival of cold weather. At high elevations and latitudes, both the reproductive and growing seasons are reduced (Table 4), but not necessarily in the same proportion. In Oregon, where growing seasons are short, hatchlings from late clutches may not appear until late August, leaving little time for growth before hibernation is necessary. Some of these individuals do not mature in time to reproduce the next spring even though they are only one to two months younger than many individuals of the breeding population. The probability that offspring from late clutches will survive to mature and reproduce in their second year must be relatively high, otherwise females which deposit late clutches would

[1] Iteroparous organisms reproduce several times during an individual's life, whereas semelparous organisms reproduce only once. (Ed.)

be at a selective disadvantage. Late season offspring may increase their survivorship by not breeding in their first year. Although this is a testable prediction, the data necessary to do so are not available.

Reduced clutch frequency in northern utas (Table 4) is imposed by the shorter reproductive season. Because northern utas do not increase clutch size to compensate for reduced clutch frequency, annual fecundity per female is markedly decreased in northern populations. In order for these populations to sustain themselves with such low fecundity, either the rate of adult recruitment must be higher, or adult longevity must be greater, or both, compared to southern populations. There are no data for egg and juvenile survivorship for Oregon utas, but Tinkle (1967b) reported that crude survivorship of juveniles was slightly lower in Texas (15 percent) than in Colorado (20 percent) at higher elevation and latitude. If this apparent trend is consistent, then increased juvenile survivorship may in part compensate for reduced fecundity at higher latitudes. However, increased adult longevity is likely to be the most important compensatory mechanism.

If the long hibernation of northern utas is factored out and only the active season considered, average adult life expectancy may not be nearly so different across populations of *Uta.* Similarly, the expected lifetime reproductive output of females is equalized to some extent across populations because of the increased expected number of reproductive seasons for females in northern populations. When the detailed data are available, it may be necessary to compare life tables which have been adjusted to account for the hibernation period in order to understand fully geographic variation in life history patterns.

There is some indication that latitude and altitude interact to restrict the northern limit of the range of *Uta* in central Washington. Utas are found only at relatively low elevations in northern Oregon and south-central Washington. The senior author has observed utas at the northern extremity of the range in Washington only in low valleys along the Columbia River at elevations of 210-250 meters. Slightly to the south in the Rattlesnake Hills of Washington, Rickard (1968) found utas abundant along a transect up to 281 meters, but none was found above this elevation. Rickard thought decreasing temperatures stopped utas at this elevation. It seems likely that the growing season becomes too short to allow *Uta* to expand its range northward and upward in this region. It is noteworthy that two other species of oviparous lizards *(Sceloporus graciosus, Gerrhontus multicarinatus)* and four species of oviparous snakes *(Contia tenuis, Diadophis punctatus, Hypsiglena torquata, Masticophis taeniatus)* are limited south of this region. With few exceptions, only viviparous species of reptiles are found at higher elevations and latitudes in the Pacific Northwest.

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Association News

The annual meeting of the officers, trustees and section chairmen was held at Portland State University on Saturday, October 9, 1976.

Reports from the Secretary, Treasurer and Editor were presented and approved.

The new Editor, Dr. Adolph Hecht, of the W.S.U. Botany Department, was welcomed and received official recognition.

Plans for the spring meeting in Monmouth, Oregon, at Oregon College of Education on March 24, 25, and 26, 1977, were discussed.

President Ken Holmes named Dr. Guy Rooth as General Chairman and Dr. Walter Bell as Program Chairman for the meeting.

A proposed symposium on "Coastline Environment of the Pacific Northwest" is in the planning stages.

Registration fees for the meeting were set at $10.00 for regular members, $3.00 for student members and no charge for students presenting a paper.

Don't forget to get your dues in to Treasurer Naskali *before* Jan. 1, 1977 — $7.00 for regular and $3.00 for student members.

Milton M. Mosher
Secretary

Northwest Science

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